DEPT. OF NATURAL RESOUCES
TIDEWATER ADMINISTRATION

THE TRIDENT REPORT ON INTERIM BEACH MAINTENACE AT OCEAN CITY

Maryland: Dept of Natural Resources

PRELIMINARY REPORT

INTERIM BEACH MAINTENANCE AT OCEAN CITY

Prepared for

ENERGY AND COASTAL ZONE ADMINISTRATION
DEPARTMENT OF NATURAL RESOURCES
STATE OF MARYLAND
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1.0 INTRODUCTION

This report has been prepared by Trident Engineering Associates, Inc., of Annapolis, Maryland, for the Energy and Coastal Zone Administration of the Department of Natural Resources (DNR) of the State of Maryland, Contract No. C15-79-440. This is a preliminary report for Coastal Resources Advisory Committee (CRAC) and DNR review to select two or three alternative strategies for further study by Trident. The Draft Final Report will contain this material plus additional studies and recommendations for a State plan of interim restoration and maintenance actions to be implemented prior to the long-range plans of the Corps of Engineers.

1.1 CORPS OF ENGINEERS ON-GOING STUDY

The principal on-going study of the erosion problem is the cooperative beach erosion control study of the Ocean City shorefront now underway by the U. S. Army Corps of Engineers, Baltimore District (see Appendix A for the Corps of Engineers' plans for Ocean City beach protection.) It is estimated that 5 - 10 years will elapse before the Corps' study will be completed and funds provided to undertake any remedial measure recommended.

2.0 SEDIMENT MOVEMENTS AND HISTORICAL CHANGES

2.1 SEDIMENT MOVEMENTS AND QUANTITIES

2.1.1 The Sediments

For the purpose of this report, sediments are considered to be the sand size particles in the shore environment. These sediments range from about 0.01 mm up to several millimeters in size. There are finer sediments present, particularly in the bays behind Fenwick and Assateague Islands, but these finer sediments play an insignificant role in stabilizing the shore face. The median grain size of the sand composing the beaches in the Ocean City area is about 0.4 to 0.5 mm.

2.1.2 Sediment Movements

Sand is moved along the shore face by the waves and currents in the beach zone. The primary force moving the sediments is the wind-generated ocean waves which strike the shore face. Two distinct sand movements result from the wave action, as described below.

2.1.3 Alongshore Movement

Most of the waves striking the beach face arrive at an angle to the shore. These waves generate a slow-moving current along the shore and also stir up the sand from the bottom. The sand stirred from the bottom and temporarily placed in suspension by the waves is then moved along the shore with the alongshore currents generated by these same waves. This result is a mass movement of sand along the shore face. This sand movement is referred to as the "alongshore drift", or the "littoral drift". A reversal in the wave direction with reference to the shore will result in a reversal of the direction of the alongshore sand drift. The quantity of this alongshore drift varies greatly around the United States shores, being less than 100,000 cu. yds. per year on much of the Great Lakes shores and well over 1,000,000 cu. yds. per year on much of the Pacific Coast.

2.1.4 On-Shore/Off-Shore Movement

Waves can be thought of as short waves or long waves. Short waves are those generated by winds of a local storm. A local observer can both see the wave and feel the winds generating the waves. These short waves (or local storm waves) tend to pull the sand off of the upper sections of the beach and carry it seaward where it is deposited in off-shore bars. Conversely, waves from distant storms reach the shore as long waves (or swells). These long waves tend to remove the material from the off-shore bars and bring it back to the beach face to create a wider beach berm. Most of our ocean beaches go through intermittent cycles of erosion and accretion in consonance with the succession of storm and non-storm occurrences on the shore. A winter storm will usually erode our Atlantic Coast beaches while the quieter periods between storms will usually witness some recovery of the beach width.

From the above description, it is seen that the sand on the beach face is constantly in motion, both in the form of alongshore drift and off-shore/on-shore movement. Mathematical equations are available relating the rate of alongshore drift to wave height and, to a lesser extent, for estimating the rate of erosion of the shore face during the storms. These mathematical relations are, however, not yet perfected, and the more reliable estimates are based on field observations in the locality or on hydraulic model test results, provided the tests are made at a sufficiently large model scale.

2.2 SEDIMENT MOVEMENT PATTERNS

The wave action in the North Atlantic area is predominately out of the northeast quadrant. Thus, the exception would be that the beach sand along the Atlantic shore would be moved from north to south. This is true in most sections of the Atlantic shore; however, local shoals and tidal currents associated with the mouths of large estuaries can reverse this pattern in some areas. Thus, the Delaware coast from Cape Henlopen south to about South Bethany Beach shows a dominant littoral drift to the north due to the tidal currents and shoals at the mouth of Delaware Bay. A similar situation is found at Virginia Beach, Virginia, where the shoals and tidal currents at the mouth of the Chesapeake Bay cause a northerly drift. However, along the present study area from the Maryland-Delaware border to the Maryland-Virginia border and beyond, the dominant direction of littoral drift is to the south.

From the above description, it is seen that the beach face between Delaware Bay and Ocean City inlet is losing sand in both directions: north to Cape Henlopen and south to Ocean City Inlet. With no sand source acting to replace these losses, the shore face can be expected to erode as a continuing action. The loss south toward Ocean City Inlet is estimated from field measurements of sand accumulations behind the north jetty and in the shoal areas associated with the Inlet to be in the order of 150,000 to 200,000 cu. yd. per year. A figure of about 150,000 cu. yd. per year seems to be the most acceptable figure and can be used with some confidence as the measurements of the sand accumulation behind the north jetty at Ocean City are fairly accurate.

Some additional losses occur from wind blowing the sand westerly off of the beach face (known as "deflation") and from sand transported seaward to such depths during very violent storms that it is more or less permanently lost from the shore face. Thus, we find that the beach area from about South Bethany southerly to Ocean City Inlet is losing material in three ways:

- South to the Inlet and beyond;
- West by wind deflation, and
- East to deep water by storm waves.

The loss to the south has been evaluated fairly accurately and is considered to be the most significant loss. The loss to the west by wind action is small. The loss to deeper water (seaward of the - 30 foot contour) by storm waves may be of some significance.

It should be recognized that at times waves from the southeast quadrant move the sand northward along the shore. However, the wave energy from the northeast quadrant is significantly greater than that from the southeast, resulting in a net drift of beach sand to the south. The gross rates are believed to be about 450,000 cu. yd. per year northerly against 600,000 cu. yd. per year southerly, giving a net drift of 150,000 cu. yd. per year to the south.

2.3 HISTORICAL RECORDS

As pointed out above, the beach face between South Bethany and Ocean City Inlet is supplying about 150,000 cu. yd. per year of material to the Inlet area and the shores of Assateague Island. Before the opening of Ocean City Inlet in 1933, this 150,000 cu. yd. per year moved directly onto Assateague Island and helped to sustain that Island from erosion. Since 1933, however, most of this 150,000 cu. yd. per year has been deposited in the shoals inside and outside of the throat of the Inlet.

This 150,000 cu. yd. per year movement to the south has, no doubt, been in effect since historical times and probably for many centuries before. Thus a more or less continuous retreat of the shore face could be expected. That this is the case is shown by the historical records of the position of the shoreline over the past century. The oldest reliable survey was made in 1849 by the U. S. Coast and Geodedic Survey (the C.& G.S.) and depicts the location of the high water shoreline and certain off-shore contours. Several later surveys are also available, notably the C.& G.S. of 1929, four years before the opening of Ocean City Inlet. This 1929 survey serves well as a base for determining the effects of the Inlet and the Inlet jetties on the adjacent shorelines. The C.& G.S. surveys of 1947 and 1965 enable the progressive changes in the shore area to be determined.

In addition to the C.& G.C. surveys, there are a number of aerial photographs and several sets of beach cross-sections (profiles across the shore face) which have been taken. These records are also very useful in delineating the changes in the shore zone.

2.3.1 Changes in the Shoreline

The successive locations of the high water shoreline (the mean high water shoreline) provide a very good index of the magnitude and type of changes (erosion or accretion) taking place along the shore. The mean high water elevation is 3.5 feet above mean low water datum plane at Ocean

City. The changes in the Ocean City shore face have been examined by comparing the C.& G.S. surveys of 1850, 1929, and 1965. The profile comparison plots made by the Baltimore District of the Corps of Engineers were used in making these numerical comparisons. The results of this examination are given in Table 1. For the purpose of the analysis, the table has been subdivided into nine one-mile sections, with section 1 being the final mile north of the inlet; and section 9, the mile adjacent to the Maryland-Delaware line. Section 1 is so completely dominated by the impounding effect of the north jetty that its changes have been listed separately in Table 1 and not included in the average of the other eight sections.

Changes 1850-1965

These changes are indicated by the shoreward movement of the mean high water (MHW) lines. Sections 2 through 9 retreated an average of 246 feet toward the shore during this 115-year period with the average retreat being 2.1 feet per year. The mile section showing the maximum retreat was Section 3 (about 25th Street to 37th Street) which retreated 430 feet during the 115 years for an average retreat of 3.7 feet per year. The mile section showing the minimum retreat was Section 7 which retreated a net of 75 feet during the 115 years, for an average of 0.7 feet per year. This section is in the area of 114th Sreet to 127th Street.

TABLE 1

ONE MILE SECTION	CORPS OF ENGINEERS PROFILES	SHOREWARD MOVEMENT OF CONTOUR POSITION [2] (in feet): 1929 vs. 1965 MHW	1929 vs. 1965 -10 Contour	1929 vs. 1965 -20 Contour	1849 to 1965 MHW	Avg. per Year 1849 to 1965	Avg. per Year 1929 to 1965	LOSS OF SAND IN CU. YDS. [2] BETWEEN MWH AND -20 FOOT CONTOURS 1929-1965: MHW to -10 Contour	-10 to -20 Contour	MHW to -20 Contour	LOSSES SEAWARD [2] OF -20 FOOT CONTOUR: Approximate Total 1929-1965
Mile 9	37-34	52	220	292	248	2.2	1.4	440,000	385,000	825,000	1,486,000 yd³
Mile 8	33-31	83	227	391	217	1.9	2.3	480,000	463,000	943,000	1,173,000 yd³
Mile 7	30-27	130	297	322	75	0.7	3.6	558,000	751,000	1,309,000	1,267,000 yd³
Mile 6	26-23	107	307	542	140	1.2	3.0	751,000	787,000	1,538,000	1,971,000 yd³
Mile 5	22-19	115	280	125	215	1.9	3.2	702,000	771,000	1,473,000	485,000 yd³
Mile 4	18-15	48	280	320	330	2.9	1.3	466,000	596,000	1,062,000	602,000 yd³
Mile 3	14-10 [no 12]	70	157	457	430	3.7	1.9	486,000	418,000	903,000	1,228,000 yd³
Mile 2	9-6	102	68	315	315	2.7	2.8	11,000	207,000	218,000	1,447,000 yd³
Contour Average Change and Quantity Totals [1]		86	252	350	236	2.0	2.4	3,894,000 4,944,000 [3]	4,378,000 4,378,000 [3]	8,271,000 9,322,000 [3]	9,659,000 yd³
Average per Year		2.4	7.0	9.7	2.0	2.0	2.4	108,200 137,400 [3]	121,600 121,600 [3]	229,800 259,000 [3]	268,000 yd³/yr
Mile 1	5-1	420	314	438				613,000	470,000	1,083,000	2,722,000 yd³
Average per Year		11.7	8.7	12.2	0.8	0.8	11.7	17,027	13,055	30,083	75,600 yd³

Footnotes: [1] *Mile 2 is not included in average contour position but is included in quantity averages.*
[2] *Circled figures represent accretion.*
[3] *These figures include the 1,050,000 yd³ emergency deposit in 1962.*

Changes 1929-1965

These changes are more indicative of present tendencies as this 36-year period begins only four years before the opening of the inlet. Comparisons of these two surveys have been made in two ways:

- By the comparisons of the shifts in the MHW, the -10 foot, and the -20 foot contours, and
- By the quantitative changes in the amount of sand between the MHW, the -10 foot, and the -20 foot contours.

As might be expected, these comparions show a great advance seaward of the contours in section 1, as well as a large accumulation of sand. These effects are, of course, due to the north jetty being built in the 1930's.

Contour Shifts 1929-1965

The survey comparisons (see Table 1) show the following contour shifts for the seven miles of sections 3 through 9. All figures represent a landward shift of the contours.

	Over the 36-Year Period	Average per Year
MHW contour	86 feet	2.4 feet
-10 foot contour	252 feet	7.0 feet
-20 foot contour	350 feet	9.7 feet

The figures in the above tabulation show that the entire shore face of sections 2 through 9 is shifting shoreward. At the mean high water line (MHW), this shift averaged about 2.4 feet per year for the 36-year period. The comparable figure for the 115-year period (1850-1965) is 2.0 feet per year, indicating that the MHW contour has moved shoreward at a fairly uniform rate over the past 115 years. Due to the north jetty, section 1 has, of course, shown a seaward movement of the contours during this period as has section 2 to a lesser extent.

The shoreward movement of the -10 foot and -20 foot contours over the past 36 years have been much greater than that of the MHW contour. This, of course, means that deeper water is moving close to the shore and that the shore face is steepening between the -20 foot and MHW contours. This deepening, in turn, permits higher waves to move closer inshore and thereby subject the beach area around the MHW contour to attack by higher waves. These higher waves could, of course, be expected to tend to increase the rate of erosion of the shore face.

Quantity Changes 1929-1965

The effect of the shoreward shifts of the MHW, -10 foot, and -20 foot contours on the quantity of sand in the near-shore zone is also of interest. Table 1 shows that the following quantites of sand have been lost from the eight miles of sections 2 through 9 as follows:

Sections 2 through 9	1929-1965 Time Period	Average per Year
Between MHW and -10 foot contour	3,894,000 yd^3	108,200 yd^3
Between -10 ft and -20 ft contour	4,378,000 yd^3	121,600 yd^3
Between MHW and -20 foot contour	8,272,000 yd^3	229,800 yd^3

Note: The above computations were made with the 1965 positions of the contours as the basis of the measurements.

The one mile of section 1 was accreting during this period, accretion between the MHW and -20 foot contour being 1,083,000 yd^3 for the 36-year period or an average of 30,100 yd^3/yr. Actually, most of the 1,083,000 yd^3 total accreted during the first few years after the construction of the north jetty in 1934.

The 8,272,000 yd^3 lost from the eight miles of sections 2 through 9 is an average loss of 196 yd^3 per foot of shorefront over the 36-year period, 1929-1965. On a yearly basis, these figures represent a loss of 229,800 yd^3 per year overall.

Actually, the loss from the near-shore area during the 1929-1965 period was greater than the 8,272,000 yd^3 (229,800 yd^3/yr) presented above as these figures could be computed accurately only to the 1965 location of the -20 foot contour. The survey profiles received from the Baltimore District Corps of Engineers show losses seaward of the -20 foot contour. However, as the 1929 and 1965 profiles did not always close seaward of the -20 foot contour, it was not possible to make an accurate computation of these further losses. Comparisons that were possible indicated, however, that the 36-year losses seaward of the present -20 foot contour out to the -30 foot contour totaled about 9,660,000 yd^3, or 6.4 yd^3/year per foot of shore. This is of the same order as the loss (8,272,000 yd^3) measured between the MHW and - 20 foot contour over this same 36-year period interval. Thus the total loss over the eight miles frontage would appear to be 17,932,000 yd^3 between the MHW and the - 30 foot contour.

The March 1962 Storm

The northeastern storm of March 6-8, 1962 resulted in severe damage to the shore between Montauk Point on Long Island and Virginia Beach, Virginia. Emergency shore protection, funded by the Federal Government, was undertaken after this storm and Ocean City was included in the project. The Ocean City area included was the northerly eight miles, extending from the Maryland-Delaware line to within about one mile of the inlet. The emergency measures undertaken involved the placement of a sand dike along the beach. The quantity of sand placed in the eight mile dike at Ocean City was 1,050,000 yd^3 according to the records of the Baltimore District. This would be an average of 24.8 yd^3 per foot of shore. This sand was dredged from deposits in Assawoman, Isle of Wight, and Sinepuxent Bays and had a medium grain size of from 0.18 mm to 0.35, depending on the source. This sand was not a good match with the 0.4 mm sand characteristic of the Ocean City shore and, therefore, probably eroded more easily than would the coarser sand. The dredged sand was, however, the only practicable source for the emergency. This 1,050,000 yd^3 placed on the shore should be added to the quantity eroded which would actually result in a loss of 1,050,000 yd^3 greater than the erosion figure of 8,272,000 yd^3 quoted above for the area between the MHW and -20 foot contours. This revised total would then be 9,322,000 yd^3 or 258,900 yd^3 per year, or 6.1 yd^3 per year per linear foot of shorefront. These figures do not include the losses between the -20 foot and -30 foot contours. These losses increase the figure to 12.5 yd^3/year per foot of shore.

2.3.2 Section 1

The accumulation in section 1 between the -20 foot contour and -30 foot contour was about 2,722,000 yd^3 over the same 36-year period, 1929-1965, or roughly about 2.5 times the amount accumulated (1,083,000) between the MHW and the -20 foot contour during this same interval. In addition to the above quantities, a total of 1,008,000 yd^3 accumulated in section 1 between the MHW contour and the boardwalk in this 36-year period. Thus we find that in section 1 (the mile of shore front north of the north jetty) a total of 2,722,000 yd^3 plus 1,083,000 yd^3 plus 1,008,000 yd^3, or 4,813,000 cu. yd. total, had accumulated in section 1 between the boardwalk and the -30 foot contour in the 36-year study interval. This is a total of 4,813,000 yd^3 accretion in this one-mile section or an average of 133,694 yd^3 per year. It should be noted that this 4,813,000 yd^3 accretion includes part of the material forming the outer bar at the Inlet. It also includes any material pumped onto this section during dredging operations in the Inlet. (The Baltimore District dredging records indicate that some 40,000 yd^3 were added to the section in this fashion.)

- Average gain per year (1929-1965) MHW to -20 feet

  Average gains for this mile......30,000 yd^3 per year

  Average gain per foot............ 5.7 yd^3 per year

  Note: The gains per year over this southerly one-mile section are probably not realistic as most of the gains probably took place over the first few years of the 36-year period until the impoundment capacity of the north jetty had been reached.

2.3.3 Sections 2 through 9

The loss of 9,322,000 yd^3 inside the -20 foot contour between sections 2 through 9 (259,000 yd^3/yr) has, of course, resulted in deeper water moving closer inshore which, in turn, has permitted more wave energy to reach the beach face. This increase in wave energy has resulted in an erosion of the beach face; thus, resulting in the action causing the difficulty on the Ocean City shore front.

Stated another way, the deepening of the off-shore contours results in the waves trying to reestablish the former normal profile of the beach. The waves can do this only by eroding sand off of the beach face and using this sand to fill the off-shore area, thereby restoring the normal beach profile. Either way, the profiles of the northerly eight miles are shifting shoreward (or are tending to shift shoreward).

2.4 SUMMARY OF VOLUME CHANGES

The data presented show that there was a massive loss of sand from the near-shore area over the 36-year period, 1929-1965. The losses for the northerly eight miles (sections 2 through 9) can be summarized as follows:

<u>1929-1965 Time Period</u>

- 36-Year Loss Between MHW and -20 Foot Contour

  Total loss for 36-year period............9,322,000 yd^3
  Average loss per mile of shore...........1,165,000 yd^3
  Average loss per foot of shore........... 220 yd^3

- Average Losses per Year Over the 36-Year Period

  Average loss per year of entire 8 miles...259,000 yd^3/yr
  Average loss per mile of shore............ 32,400 yd^3/yr
  Average loss per foot of shore............ 6.1 yd^3/yr

For the southerly one mile section north of the north jetty, there has, of course, been accretion. The figures for this one mile of shore are:

° Gain Between MHW and -20 Foot Contour

Total gain over 36-year period..........1,083,000 yd^3

Average gain per mile of shore..........1,083,000 yd^3

Average gain per foot of shore......... 205 yd^3

Average gain per foor of shore per yr... 5.7 yd^3/yr

2.5 BEACH CONTOUR SHIFTS

The erosion of the shore face is the most noticeable result of the loss of material from the shore. A study of the position of the MHW contour in 1849 and 1929 shows that the Ocean City shoreline has historically been undergoing erosion. As shown in Table 1, the mean high water (MHW) contour shifted shoreward an average of 2.3 feet per year for the 79-year period, 1850-1929. The average rate for this same frontage for the succeeding 36-year period, 1929-1965, was 2.4 feet per year. For this latter figure, only the northerly seven miles was used as the MHW contour over the southerly two miles accreted during this period due to the presence of the north jetty.

The erosion rate at the MHW contour was very constant over the area for the 116-year period, 1849-1965. These yearly rates give a cumulative shift landward of the MHW contour of 184 feet over the first 80 years and 86 feet over the succeeding 36 years for a total of 270 feet for the entire 116-year period. The 86-foot retreat over the past 36 years is the figure of greatest interest as it reflects the erosion rate since the time of greatest growth of Ocean City, starting about 1930.

The average shoreward retreats of the -10 foot and -20 foot contours over the 36-year period (1929-1965) were 252 feet and 350 feet respectively over the northerly seven miles. These figures represent rates of 7.0 feet per year and 9.7 feet per year respectively.

Shore Changes 1965-1979

The most comprehensive recent survey is the 1979 set of profiles made by the Baltimore District of the Corps of Engineers. Only 20 of the 36 profiles of the 1965 survey were repeated in the 1979 survey. However, these 20 profiles were spaced at fairly regular intervals and enabled a comparison between 1965 and 1979 conditions to be made along the entire nine miles of shore. The changes in volumes and in contour locations are indicated in Table 2 and are discussed below.

TABLE 2

ONE-MILE SECTION	CORPS OF ENGINEERS PROFILES	SHOREWARD MOVEMENT OF CONTOUR POSITION (in feet) 1965 to 1979			SHOREWARD MOVEMENT PER YEAR OF MHW CONTOUR		LOSS IN YD.³ BETWEEN MHW AND -20 FOOT MLW CONTOURS 1965 to 1979		
		MWH	-10 Ft.	-20 Ft.	1929 to 1965	1965 to 1979	MWH to -10 Ft.	-10 Ft. to -20 Ft.	MHW to -20 Ft.
Mile 9	37, 35	20	77	70	1.4	1.4	213,000	144,000	357,000
Mile 8	33, 31	60	165	355	2.3	4.3	373,000	680,000	1,053,000
Mile 7	29, 27	37	147	202	3.6	2.6	310,400	416,000	726,000
Mile 6	25, 23	10	122	160	3.0	0.7	132,000	338,000	470,000
Mile 5	21, 19	10	82	110	3.2	0.7	113,000	167,000	280,000
Mile 4	17, 15	15	55	132	1.3	1.1	6,000	177,000	183,000
Mile 3	13, 10	47	202	250	1.9	3.4	378,000	383,000	761,000
Mile 2	9, 8, 6	57	210	322	2.8	4.1	400,000	430,000	830,000
Contour Average Change and Quantity Totals		32.0	133	200	-	-	1,925,000	2,735,000	4,660,000
Average Change per Year		2.3	9.5	14.3	2.4	2.3	137,400	195,000	332,400
Mile 1	4, 2, 1	65	15	30	-	-	286,000	5,000	281,000
Average Change per Year		4.6	1	2.1	2.3	4.6	20,400	300	20,100

NOTE: Circled figures represent accretion.

Volume Changes 1965-1979

Reference to Table 2 shows that the sand continued to be lost at a rapid rate at all depths between the MHW and the -20 foot contour. Actually, losses were in evidence out to even greater depths but quantities could not be accurately calculated due to the lack of closure between the 1965 and 1979 surveys at the seaward ends of the profiles. The losses between the MHW and the -20 foot contour are summarized below for the northerly eight miles of shore.

1965-1979 Time Period

- 14-Year Loss Between MHW and -20 Foot Contour

  Total loss for 14-year period..........4,660,000 yd^3
  Average loss per mile of shore......... 582,500 yd^3
  Average loss per foot of shore......... 110.3 yd^3

- Average Loss per Year Over the 14-Year Period

  Average loss for entire northerly 8 miles... 333,000 yd^3/yr
  Average loss per mile of shore.............. 41,600 yd^3/yr
  Average loss per foot of shore.............. 7.9 yd^3/yr

A comparison of the above quantities with the figures for the 36-year interval, 1929-1965, shows them to be of the same order — the average overall loss per year being 259,000 yd^3/yr over the former 36-year period compared to 333,000 yd^3/yr for the recent 14-year period. These reduce to 6.1 yd^3/ft of shore for the former 36-year period against 7.9 yd^3/ft of shore for the recent 14-year period. This indicates that there has been some, though not a significant, increase in erosion over the northerly eight for the later period compared to the former period.

As in the previous survey interval, the southerly one mile of shore against the north jetty showed a net accretion. In the recent interval, 1965-1979, the accretion between the MHW and -20 foot contours was 281,000 yd^3 total, or 20,100 yd^3/yr. This rate of gain was considerably less than the 30,000 yd^3/yr gain registered in the preceding 36-year period; but this could have been expected as the north jetty impoundment area is more nearly filled as the years progress.

Contour Changes 1965-1979

The data shown in Table 2 shows that the MHW, -10 foot, and -20 foot contours continued to move shoreward during the 14-year interval, 1965-1979. This movement shoreward is summarized in the following tabulation for the northerly eight miles (sections 2 through 9):

	Over the 14-Year Period 1965-1979	1965-79 Average per Year	1929-65 Average per year
MHW Contour	32 feet	2.3 feet	2.4 feet
-10 Foot Contour	123 feet	8.8 feet	7.0 feet
-20 Foot Contour	200 feet	14.3 feet	9.7 feet

This tabulation indicates that the rates of erosion are somewhat larger for the most recent 14 years than for the preceding 36 years though the rates are of the same order of magnitude.

3.0 ACTIONS BY MAN

3.1 GROINS

The previous discussions related to the shore changes at Ocean City took into consideration the effect of the north jetty and the placement of 1,050,000 yd^3 of sandfill on the beach following the March 1962 storm. There are two other actions taken by man which have influenced, in some degree, the beach contours:

- The placement of a series of groins along the Ocean City shorefront, and
- The bulldozing of sand from the lower beach face up onto the beach berm.

The groins and their results will be discussed first.

The Department of Natural Resources has supplied a listing, dated May 14, 1979, showing the record of groin construction at Ocean City (Table 3). The table shows that a total of 42 groins have been constructed at Ocean City; 14 by DNR and 28 by "others".

The 28 groins construction by "others" (presumably by the Department of Transportation) were constructed between 1922

TABLE 3

A SUMMARY OF OCEAN CITY'S GROIN SYSTEM

GROINS CONSTRUCTED BY OTHERS	YEAR COMPLETED	GROIN WORK BY DNR	YEAR COMPLETED	COSTS	
				ENGINEERING	CONSTRUCTION
Between S. Division and S. 1st Streets	1922-24	14th Street-Repaired outboard end	1973	$ 2,550	$ 24,020
Worcester Street	1922-24	15th Street-Stone Extension	1978	2,850	50,000
Somerset Street	1931	23rd Street-Repaired outboard end	1978	—	27,000
Talbot Street	1928	25th Street-New Groin	1974	1,420	49,700
N. Division Street	1931	29th Street-New Groin	1973	2,250	38,260
N. 1st Street	1930	31st Street-New Groin	1975	1,630	31,167
2nd Street	1931	31st Street-Revision	1978	—	10,920
Between 3rd and 4th Streets	1932	34th Street-New Groin	1978	2,500	57,604
Between 4th and 5th Streets	1931	51st Street-New Groin	1975	1,630	29,000
Between 5th and 6th Streets	1932	58th Street-New Groin	1978	2,500	56,104
Between 6th and 7th Streets	1932	71st Street-New Groin	1975	1,630	31,900
8th Street	1932	77th Street-New Groin	1974	1,630	47,700
9th Street	1934	86th Street-New Groin	1975	1,630	29,000
Between 10th and 11th Streets	1934	89th Street-New Groin	1975	1,630	29,000
12th Street	1938	91st Street-New Groin	1973	1,630	47,700
13th Street	1962	101st Street-New Groin	1975	1,630	29,000
14th Street	1930	128th Street-New Groin	1975	1,630	34,000
15th Street	1933, 1960	130th Street-New Groin	1978	2,500	56,104
16th Street	1938	TOTAL COSTS		$31,240	$678,179
18th Street	1949				
Between 19th and 20th Streets	1962				
21st Street	1951				
22nd Street	1962				
23rd Street	1951				
26th Street	1951				
73rd Street	1961				
Between 74th and 75th Streets	1961				
76th Street	1961				

and 1961. Of these 28 groins, 17 were constructed before 1939 and all of these were between 16th Street and the north jetty. Thus all of the 17 older groins are now within the sand fillet impounded by the north jetty. They are probably having little influence on the position of the beach face, except possibly those groins between 12th Street and 16th Street. In fact, the groins from 8th Street to the north jetty are buried in the sand fillet.

A set of comparisons was undertaken to determine, if possible, the effects which the groins had on delaying the erosion of the shore. One comparison attempted to utilize the fact that before 1965, all but three of the listed groins were south of 27th Street. Table 1 shows that in section 1 the MHW contour moved seaward an average of 420 feet during the 1929-1965 interval for an average of 11.7 feet per year. However, it is believed that this advance was due primarily to the presence of the north jetty constructed in 1933-1934 and not to the groins between the jetty and 7th Street. Section 2 (the next mile to the north) moved seaward an average of 2.8 feet per year during the same period, but it seems impossible to state whether this advance was due to the presence of the north jetty or the groins in this section.

Section 3, the next mile of frontage to the north, had four groins (at 21st, 22nd, 23rd, and 26th Streets), all installed after 1950. The groins were apparently designed to extend out to about the -2 foot MLW contour when constructed. Comparing section 3 to the six sections (sections 4 through 9) to the north of it, we find that in section 3 the MHW line retreated 70 feet during the 1929-1965 period, while in the six sections to the north, the MHW line retreated an average of 89 feet. These two figures, 70 feet and 89 feet, are so close in magnitude that the only logical conclusion would seem to be that the four groins in section 3 did not appear to have a measurable effect in slowing down the retreat of the MHW contour in section 3.

Another comparison was available on a drawing furnished by the Shore Erosion Control Program of the DNR, "Beach Profile Comparison at Selected Groins in Ocean City, August 3, 1977". This drawing shows the groin profiles as constructed together with a beach profile for the year preceding the construction of the particular groins. These groins and their dates of construction are 25th Street (1974), 29th Street (1973), 31st Street (1975), 51st Street (1975), and 128th Street (1975). Also shown on the drawing are beach profiles on each side of the five groins as of August 3, 1977.

A study of these groins and profiles shows the following:

- The groins at 29th, 51st, and 128th Streets showed an appreciable accretion of sand on both sides of the groins between construction and August 3, 1977 — the accretion being in the order of three or four feet.

- The accretion on the landward half of the 51st and 128th Streets groins carried well above the top of the groins so that this part of the groin was buried. This building above the groin is sometimes considered as an indication that the accretion is not due to the groin but to other causes.

- The 1977 profiles were taken near the end of the summer (August 3) when the beaches are usually at their most accreted position of the year. The before-construction profiles were taken, in four cases, between January and May when lower beach profiles could usually be expected. Thus some of the accretions could be attributed to a seasonal effect rather than to the presence of the groins.

In view of the above findings, it is concluded that the comparative profiles on the 1977 drawing cannot be taken to show, with assurance, that the five groins are a stabilizing influence on the beach. This conclusion is reinforced by an analysis of other data as described below.

A set of drawings produced by the Maryland Geological Survey show repetitive profiles over several years at 12 places along the shore. Other locations were shown also but without a vertical datum control. These repetitive profiles showed that vertical variations in beach elevation near the mean high water line of as much as six feet could be expected in a four-month period and ten feet or more over a year or two. Fluctuations of four to six feet were commonplace. These wide and rapid variations make a beach elevation measurement on a given day a matter of chance and not indicative of a meaningful long term erosion or accretion of the upper portion of the beach face from MHW to the crown of the beach. Thus , it seem impossible to use this data to assess the value — or lack of value — of the groins in stabilizing the beach face.

Summarizing the attempts made in the above paragraphs to assess the value of the existing groins in stabilizing the beach face at Ocean City, the conclusion seems justified that there is no firm evidence that the groins have been effective in stabilizing the beach face. Possibly, there has been some beneficial effects from the groins; but these effects, if present, do not seem to be sufficiently great to be detected by analyzing the existing data. Local observers may well have seen sand action around the groins which indicate that the groins have a beneficial effect; however, the firm data at hand does not permit a firm conclusion of this type to be drawn.

3.1.1 Discussion of the Ocean City Groins

The effects of a groin become more noticeable as the length and height of the groin is increased. The north jetty at Ocean City acts as a long, high groin and has been very successful in impounding a large fillet of beach for a mile or so to the north of the groin.

The standard Ocean City groins constructed between South 1st Street and 130 Street are approximately 201 feet in length and extend out only to about the -2 or -3 foot MLW contour. The question then arises as to whether or not the Ocean City groins are of sufficient length to produce an impoundment of sand against the shore. This question is probably not susceptible of a definite answer and reliance could probably best be put on the basis of experience. The "Shore Protection Manual" of the U. S. Army Corps of Engineers (1977 ed.) includes a section on the design of groins which is based on wide experience with groins. Excerpts are quoted from this manual in Appendix B.

A comparison of the standard groins at Ocean City with the guidelines stated in the Appendix B excerpts show that the Ocean City groins, as designed, cannot be expected to function to full effectiveness. The two prime reasons for lack of full effectiveness are:

- The groins are only 201 feet in length and thus extend, in most cases, only to about the -2 foot MLW contour and in some cases, even less. The recommended depth quoted from the <u>Shore Protection Manual</u> for the Atlantic Coast is -6 foot MLW. Thus, the groins do not extend seaward to a sufficient depth to trap and hold a large portion of the sand drifting along the shore.

- The groins are 201 feet in length, of which some 150 feet could be considered as the length seaward of the crest of the beach berm. The Manual recommends that, to be effective, the groins be spaced at two to three times this berm to seaward distance. Applying this guideline to Ocean City groins, the spacing indicated would be 150 x 3 = 450 feet. In actuality, the northerly eight miles (42,200 feet) of the Ocean City frontage has a total of 28 groins. This represents an average spacing of 1,510 feet per groin instead of the recommended 450 feet. In other words, the present groin system has an average spacing of about three times the recommended spacing. This would indicate that the groin system could not be expected to function at maximum effectiveness in stabilizing the shore.

In view of the two points described in the preceding paragraph, it could be concluded that the present groin system should not be expected to provide effective stabilization of the shore. The groins have, no doubt, had some beneficial effects. However, as pointed out previously, it does not seem possible — with existing data — to define the degree of benefit from the groins.

3.2 SAND BULLDOZING

Over the past three or four years, Ocean City has utilized bulldozers to push the sand from near the mid-tide line up higher on the beach face. This provides a wider beach berm at the expense of lowering the beach elevation near the mean sea level line. Due to the nature of the bulldozing operation, it has not been practicable to obtain a usable estimate of the quantity of sand moved in this fashion. Apparently, the bulldozer would work after each winter storm to push the sand back up on the beach berm. The total cost of these operations was reported by the City to have been $465,315 for the winter period 1977-78 (late Sept. 1977 to early May 1978).

On some of the beach profiles referred to above, there are mounds of sand shown up near the crest of the berm. It is presumed that these clearly identifiable mounds are the sand rows or mounds which have been pushed up by the bulldozers. Of 12 sand mounds so identified, the cross-sectional areas varied from about 60 square feet to 175 square feet, with an average area of about 110 square feet. The possible effectiveness of these sand mounds in delaying the erosion of the shore face during storms accompanied by heavy wave action is examined below.

3.2.1 Effectiveness of Bulldozing

No surveys or profiles have been taken to measure the quantities of sand bulldozed during this time period. It is, therefore, impossible to quantify the effectiveness of the sand mounds in reducing or delaying shore erosion. There are, however, certain laboratory tests which have been made at full scale at the U. S. Army Coastal Engineering Research Center which can give some indication of the probable effect of the sand mounds. The tests at the Coastal Center were made in a large wave tank some 600 feet long by 15 feet wide by 20 feet deep. During the studies referred to, ordinary sand beaches were subjected to attack by storm-type waves up to six feet in height. These tests showed that these waves eroded the shore face rapidly at first, but that the rate of erosion decreased somewhat as the shore face was eroded and the eroded sand was deposited near the breaker line. The results of a test made with storm waves of a height of 5.5 feet and a wave period of 11.3 seconds showed that the beach face eroded during the first hour at about 60 square feet per hour. For the fifth hour, the erosion rate was about 30 square feet; and for the tenth hour, about 22 square feet per hour. Using 110 square feet as the cross-section of the sand mound (or sand row) pushed up by the bulldozers at Ocean City, it can be reasoned that the sand mound would delay erosion by about two hours. In other words, the sand mound conceivably provided a fair degree of protection for the first two hours, but would probably have little or no effect after that time. Thus the degree of effectiveness of the bulldozing would be related to the duration of the storm.

Relating the above to effectiveness, it would appear that for a storm lasting through only one high tide (i.e., a storm of say 8 to 12 hours), the bulldozing probably has some beneficial effect, considering that high tide lasts for only two or three hours. But for longer storms lasting through two or more high tides, the effect of the bulldozing would be very much diminished. If the near-shore depths continue to deepen, as described in the paragraphs above, the time will arrive when the beach face between the mean low water line and the boardwalk or shore line will become so narrow that the bulldozing will lose whatever effectiveness it has under present conditions.

3.3 THE INLET JETTIES

The inlet jetties, particularly the north jetty, have had a very pronounced effect on the hydrography of the area. Insofar as the Ocean City beach frontage is involved, the north jetty has created a massive impoundment of sand which blankets the most southerly mile of shore up to about 9th Street and to a lesser extent for another mile north up to about 22nd Street. Over the 36-year interval, 1929-1965, the mean high water line over the first mile advanced seaward an average of 420 feet, and over the second mile, an average of 102 feet. Over this same 36-year period interval, the off-shore area in the first mile accumulated over 1,000,000 cu. yd. between the MHW and the -20 foot contours. (These changes resulting from the installation of the north jetty are discussed in more detail in preceding paragraphs.)

The impoundment of material by the north jetty has, of course, benefited the Ocean City beach to the north of the jetty and has also benefited the inlet navigation channel by preventing some of the material from moving into the inlet. The north jetty has not, however, impounded all of the southward moving littoral drift, and much has moved into the inlet. Once in the inlet, the tidal currents in the inlet have tended to move the material seaward to form an outer bar, and landward to form shoals in the bay area immediately behind the inlet. These bars and shoals have, of course, necessitated the dredging of the inlet navigation channel from time-to-time. (The inlet opened by natural causes in 1933, and the north jetty was built in 1934 - the south jetty in 1935. The north jetty presently has an elevation of +9.0 ft. MLW and the south jetty an elevation of +6.0 ft. MLW.)

The inlet navigating channel is maintained by the U. S. Army Corps of Engineers at a depth of about 10 feet MLW. As of 1971, the Baltimore District of the Corps reported that the maintenance dredging required was, on the average, about 63,000 cu. yd. per year to maintain a 10-foot channel. The material from the dredging has been placed in selected areas in Sinepuxent Bay and, to a lesser extent (about 40,000 cu. yd.), on the beach front north of the north jetty. The shoal areas of the outer bar and in the bay areas behind contain significant quantities of the sand which was moved into the inlet by the littoral drift of sand and then deposited in the bars and shoals by the action of the tidal currents in the inlet.

3.4 JETTY EFFECT ON ASSATEAGUE ISLAND

Although the inlet has provided a valuable navigation feature to the Ocean City area and provided a better exchange of the waters of the ocean with the waters of the bays behind Fenwick and Assatague Island, the inlet has had a disastrous effect on the northly three of four miles of Assateague Island. The sand that moves southerly along the Ocean City frontage moved directly onto Assateague Island before the inlet opened in 1933. This sand - something in excess of 150,000 cu. yd. per year - was able to sustain the northern end of Assateague Island on essentially the same shore face alignment as Ocean City. However, since the breakthrough of the inlet in 1933 and the construction of the jetties in 1934-35, very little sand has been able to move south past the inlet. This has resulted in a massive erosion of the shore face of the northerly three or four miles of the island. In fact, at a point on the shore two miles south of the inlet, observations (Gawne) show that the beach face retreated about 800 feet between the years 1943 and 1963, or at an average rate of 40 feet per year. During the same 20-year period, the shore at a point seven miles south of the inlet - not yet influenced by the inlet - retreated only about 150 feet, or an average of about 6.5 feet per year. This massive retreat of the northerly three miles of the island has almost resulted in the flanking by the tidal flow of the west end (the shore end) of the south jetty and, in fact, permitted a large breakthrough of this sector of the island during the March 1962 storm. This breakthrough, or breach, was filled in as part of emergency work following the storm, and the south jetty was extended landward (to the west) by 700 feet in 1964 to lessen the chance of flanking the landward end of the jetty.

Thus, it is seen that the northerly three or four miles of Assateague Island have suffered severe erosion due to the inlet and jetty complex. The island shores further south have not yet felt the effect of the inlet as these shores to the south have, up to the present, been fed by the sand eroded from the northerly three or four miles of the island. It can be expected, however, that the erosive effect will be felt further and further to the south as times goes on unless some type of corrective measure is taken.

4.0 POSSIBLE IMPROVEMENT MEASURES

4.1 GENERAL

The continuing erosion of the shore face in front of Ocean City makes it advisable to initate steps to stop the erosion or to protect, in some way, the city from severe damages resulting from the continuing erosion. The Federal government, acting through the Baltimore District of the U. S. Army Corps of Engineers, is now making a comprehensive study of the erosion problem at Ocean City; and it is anticipated that within the next five or ten years, a reasonably permanent solution to the city's problems resulting from shore erosion will be resolved by a cooperative project between the city, the state, and the federal governments. The purpose, then, of this study being made by Trident Engineering Associates for the State of Maryland is to define the various possible alternative measures which would be taken by the state and the city to serve as interim measures of protection until the more permanent solution resulting from the Baltimore District's study is forthcoming. Most of the alternatives, which will be described below, will then be cast in the frame of interim measures to carry through for the next five or ten years until more permanent measures are taken. It is quickly recognized that some of the plans described below could not be considered as interim measures. However, they are presented to give an order of magnitude of costs and time involved in the various types of possible solutions to the Ocean City erosion situation.

In describing the alternative measures, the advantages and disadvantages of the measures will be described, as well as the manner in which they would combine with the more permanent solution which will probably be put forward by the Corps of Engineers. In view of the importance of the Corps of Engineers study and proposals to the present study, it is advisable at this time to describe the present status - as Trident understands it - of the Corps study.

4.2 THE CORPS OF ENGINEERS STUDY

The Corps of Engineers study is, as stated above, being made by the Baltimore District of the Corps. Information obtained by Trident in meetings with the Baltimore District show that the District is well along with formulating what will probably be its recommended solution to the Ocean City erosion problem. The probable solution is given in several degrees of protection, i.e., protection from storms of a violence specified in terms of recurrence intervals. Storm recurrence intervals of 100 years, 50 years, 20 years, and 10 years are considered in the District's planning. The 10-year storm is the least violent of the four.

For storm protection and shore erosion control combined, the District envisions as its main feature of protection, the widening and raising of the shore front by various degrees by placement of sand from other sources to provide the required protection. The defense against the 100-year storm requiring, of course, the greatest volume of sand placement and the 10-year storm the least. The details of the present thinking of the District as to their probable plans is given in more detail in Appendix A to this report, which was furnished Trident Engineering in March 1979 by the District. Each plan inclues not only the first cost but an annual maintenance cost for replacement of sand at the rate it is estimated to be eroded from the shore face. Under these four plans, a steel sheet pile bulkhead also would be a feature in the present boardwalk frontage.

In addition to the four plans for both storm protection and shore erosion control, the District is considering four plans for only shore erosion control. These plans would not raise the beach berm as high as the storm protection plans nor would they include the bulkhead at the boardwalk. These four "shore erosion only" plans are shown in Appendix A.

4.3 INTERIM MEASURES

Possible interim measures include the following or combinations of the following:

1. Sand replenishment of the shore;
2. Bulkheads or seawalls to prevent erosion past the location of the bulkhead or seawall;
3. Revetments placed on the beach face;
4. Groins to trap sand against the beach face and slow the rates of loss by littoral drift;
5. Off-shore detached breakwater parallel to the shore;
6. Sand back-passing;
7. Shifting (bulldozing) the sand up to the higher levels of the beach face.

The following sections of the report will describe the possible adoption of the various alternatives to the needs of Ocean City. Each of these alternatives has advantages and disadvantages, which will be included in the descriptions.

4.3.1 Sand Replenishment

Much of the difficulty at Ocean City is due to the narrowness of the beach face due to the continued erosion of the shore face. As shown in Table 1, the MHW line retreated an average of 86 feet over the northerly seven miles from 1929 to 1965. Table 2 shows another 28 feet of retreat during the next 14 years (1965 to 1979). This is a total retreat of 114 feet over the past 60 years. It is evident that the replacement of at least part of the lost sand would aid in protecting the shore.

In connection with the emergency work undertaken by the Federal government after the March 1962 storm, a beach cross-section was developed which was considered to provide protection against a 10-year storm along this area of the Atlantic Coast by the construction of a "dune" crest for the section, 20 feet wide at +12 feet MLW elevation. In front of this dune crest is a berm 30 feet wide at crest elevation of +10 feet MLW. From the front edge of the berm, the beach slope is carried seaward on a 1 on 20 slope until it intersects the existing beach profile. This 30-foot wide berm is a "minimum" width; a 50-foot width of berm is much more desirable. Where there is an existing seawall or substantial bulkhead, the berm height could be reduced to +7.0 MLW and the +12-foot dune eliminated. Preliminary calculations indicate that the amount of sand required to establish a 30-foot beach with a +10-foot berm and a +12-foot dune over eight miles would be in the order of 1.5 to 2.0 million cubic yards. Widening to a 50-foot berm would add about another 30% to the quantity of initial fill.

The additional sand required to maintain the replenished shore would probably be in the order of 150,000 cu. yd./year. Actually the maintenance requirements might be more than the 150,000 cu. yd./yr. due to the fact that the offshore areas has been progressively deepening over the past 100 years or more and is probably now in what could be called a "non-equilibrium" condition. This condition might cause a semi-permanent movement of sand off the replenished beach face into deeper water and thereby increase the maintenance requirements beyond the 150,000 cu. yd./yr. indicated. The additional amount of sand that would be moved offshore in this fashion cannot be predicted from the present state-of-the-art and could be determined only from field experience. Possibly the 150,000 cu. yd./year figure should be increased by 50% (to 225,000 cu.yd./year) to provide a basis for estimating maintenance cost on the widened beach.

The advantages of this plan are as follows:

1. It would increase the recreational beach area, and present

types of beach use could be continued with very little interference.

2. It would provide a buffer to protect the backshore from damage during a moderately severe storm (a 10-year storm).

3. The plan would meld easily with the probable Corps of Engineers plan as it is basically the same as the plans most seriously considered by the Corps for recommendation.

The disadvantages of this plan are:

1. The plan does not protect the backshore against a storm of medium severity or greater (15-year storm or greater). This is particularly true if only the 30-foot berm width were adopted.

2. The yearly maintenance figure for new sand required to maintain the shore is uncertain. It might conceivably be much more (100% or more) than the 150,000 cu.yd./year first quoted as a basic figure in the preceding paragraph.

The cost of this plan (initial cost and maintenance) would depend almost entirely on the cost of obtaining, transporting, and placing required sand fill on the beach. This cost in turn depends on the location or locations of the sand to be used for replenishing and maintaining the beach.

4.3.2 Use of Very Long Groins

Groins are intended to stabilize the shore by trapping sand between the groins and by decreasing the rate of littoral drift causing losses from the shore. The exact manner in which groins function is imperfectly understood even at this date, and design is principally empirical. Considering the success of the north jetty (which also acts as a groin) in impounding sand and protecting and stabilizing the shore for at least one mile to the north, a rather final solution would be to build groins some 800 to 1000 feet in length at one mile intervals over the Ocean City frontage and to approximately the same elevation (+9 ft. MLW) as the north jetty. The groin would probably be of rock mound construction. This plan would essentially stop all sand movement along nine miles of beach and restrict sand movement to circulation within each one-mile section.

Due to the thinness of the beach over much of the present frontage, sand would have to be supplied initially to each compartment so that even when the sand was impounded mainly against the south groin, sufficient protective beach width would remain at the north end of the compartment to provide the necessary protection to the back-shore areas (the areas behind the dunes and boardwalk). The stable fillet angle is about 5° as measured in the first mile (section 1). This fill would take about 425,000 cubic yards for each of the eight one-mile sections north of the first mile; this would be a total of some 3,400,000 yd^3 of initial fill for the northerly eight miles to be placed between the groins. This fill would be absolutely required in this plan, otherwise the northerly end of each mile section would be eroded 200 feet or more back into the backshore by the time the mile section adjusted itself to the 5° fillet angle.

The advantages of this plan are as follow:

1. The erosion of the shore would probably be stopped or reduced to a very low rate;
2. Maintenance costs would be low;
3. It would increase the recreational beach area and the present types of beach use could be continued with little interference;

4. The groins could be designed to provide recreational fishing along the outer portions.

The disadvantages of this plan are:

1. It would have a very high first cost;

2. It would not meld with the probable plan to be recommended by the Corps of Engineers;

3. It would permanently eliminate the passage of littoral drift past the north jetty. This could conceivably benefit the navigation channel in the inlet but has a high potential for continuing damage to Assateague Island. This may introduce certain legal aspects into this plan of improvement.

4.3.3 <u>Use of Long Groins</u>

By long goins are meant groins extending out to about the - 6 ft MLW contours. This would require groins some 400 to 500 feet in length or somewhat over double the length of the present groins. These groins would, in effect, be in keeping with the article on groins in the Shore Protection Manual (see Appendix B).

The profile of the basic groin consists of an initial horizontal section at elevation +10.0 MLW across the beach berm, or at the location of the desired beach berm, a sloping section following the normal beach profile slope to about the mid-tide line, and a horizontal section at about mid-tide level out to the -6 foot contour. The groins could be constructed of wood piling, steel piling, or stone. Treated wood piling or stone is generally preferred due to the difficulty in maintaining steel piling against rust and abrasion in the saltwater-sand movement environment.

These groins would be from 400 to 500 feet in length and possibly longer depending on local conditions. In view of the desire to widen the beaches as a protection against storms and for more recreation area, the 450-foot length should probably be used for estimating purposes.

The spacing of the groins is another factor to be considered. The Shore Protection Manual (par. 5.664) makes a very definite recommendation in italics that

> *"The spacing between groins should equal two or three times the groin length from the berm crest to the seaward end."*

Using a berm width of 30 feet, a 450 foot groin would have a length, berm crest to seaward end of about 420 feet. Using the most liberal spacing of three times the working length of 420 feet, the recommended groin spacing would be 1260 feet, or four groins per mile, or about 32 groins for the eight miles of shore in most need of improvement.

The sequence of construction is also of concern. There are two possibilities: One is to build all the groins (or a great number of them) at one time; the other is to build the groins in sequence starting from the downdrift end (the south end in this case) of the proposed groin field. In this latter case, the concept is that the first groin would be built and then permitted to "fill" to capacity, i.e., to accumulate its complement of beach sand, and then build the second, and so on northerly up the beach in sequence. Each groin would have to trap about 47,600 cubic yard to be "full". With an estimated littoral drift rate of 150,000 yr^3/yr, the rate of groin building under this plan would be somewhat less than four groins per year. Thus a groin construction program extending over 10 years for the 32 groins would be indicated. This time is possibly unrealistic in terms of the needs of the community.

The plan for long groins becomes more realistic if it includes a plan for initial filling of the beach area between any two groins with sand when constructed in order to permit the rapid construction of groins. This would require the placement of about 47,600 yd^3 in the 1,320-foot beach spacing between adjacent groins. This would then require sandfill of about 190,000 yd^3 per mile or about 1,525,000 yd^3 for the entire eight miles covered by the 32 groins.

The advantages of this plan are:

1. A rather permanent solution to the shore erosion problem at Ocean City would result.

2. Groin maintenance costs under normal condition would be moderate, assuming well-constructed groins.

3. Beach maintenance costs would be moderate as the groins would act to retain most of the beach sand in its own beach compartment.

4. The recreational area on the beaches would be increased and the present type of beach uses could be continued with little interference.

5. Protection against 10-year storms would be attained over all the shore face and against about 25-year or greater storms for those portions of each compartment which happended to be widest when the storm struck. (Normally, this widest portion would be the southerly part of each compartment.)

6. The plan would not be counter to the Corps' probable plan.

The disadvantages of the plan are:

1. The first cost would be high.

2. If too many years were involved in adopting the Corps plan, much of this plan might be accomplished before the Corps began work.

3. The passage of littoral drift to the south past Ocean City would be essentially permanently eliminated. This could conceivably benefit the navigation channel in the inlet, but has a high potential for continuing damage (with certain legal implications) to Assateague Island.

4. A large storm (50-year storm or greater) might, in one event, pull enough material out into deep water offshore to leave the beach face again exposed to wave damage. Replacement of this sand might be necessary.

4.3.4 Use of Short Groins

Very short groins are considered as groins about 200 to 225 feet in length and extending to seaward not past the -2-foot, MLW contour. These are goins of the type which have been installed at Ocean City over the past few years. As pointed out above, it has been found impossible - with existing data - to determine quantitatively the degree to which the existing groins have had a beneficial effect on the shore. Local observers and shore front owners may well be convinced that the existing groins have had some degree of beneficial effects, but it does not seem possible to identify these effects quantitatively and to state that with the groin this happened and without the groin this other thing would have happened.

In view of this lack of certainty, or the inability to assign a positive quantitative benefit to these existing groins, it does not seem practicable to recommend a plan using this type of groin. If evidence can be obtained to identify the beneficial effects of this type of groin, then it would, of course, be possible to evaluate a plan using the very short groins.

As pointed out above, the present groins do not meet the standards given in the Shore Protection Manual in terms of length or spacing. The use of short groins could probably be considered as reasonable if the groins extended to at least the -4 foot contour and had a spacing not over three times the working length (the length from the berm crest to the seaward end) of the groin. This would call for groins in the order of 325 feet in length and spaced not over 900 feet apart. (The present "standard" groin at Ocean City has a length of 201 feet and the average spacing is 1510 feet. The present average spacing has little meaning, however, as the 28 existing groins have very irregular spacings.)

Thus, a plan using short groins can be envisioned which would involve lengthening by about 125 feet the 28 existing groins and constructing 19 new groins to give groin lengths of about 325 feet and average spacings of 900 feet. The groin construction should be supplemented by beach fill as needed to produce at least a 30-foot berm width at the +10-foot MLW contour. The amount of beach fill needed would be in the order of 1.5 million cubic yards, the same as indicated for the "sand replenishment only" plan above.

The advantages of this plan are:

1. It would increase the recreational beach area, and present types of beach uses could be continued with very little interference;

2. It would provide a buffer to protect the back-shore from damage during a moderately severe storm (a 10-year storm);

3. The plan would meld easily with the probably Corps of Engineers plan as it is basically the same as the plans most seriously considered by the Corps for recommendation.

4. The rate of annual beach nourishment would be reduced to possibly one-half of that required under the beach replenishment plan alone.

5. The groins would reduce localized erosion fluctuations below the fluctuations which could be expected with sand replenishment alone.

The disadvantages of this plan are:

1. The plan does not protect the backshore against a storm of medium severity (15-year storm or larger).

2. The first cost is considerably more than for the "sand replenishment alone" plan due to the cost of 28 groin extensions and 19 new groins.

3. A severe storm (25-year or greater return frequency) might severely erode the shore face and necessitate a massive sand replenishment program.

4.3.5 Use of Bulkhead

Bulkheads are vertical structures placed well upon the face to intercept wave attack and protect the backshore. They are usually placed above the mean high water line and are not brought under wave attack except by storm waves. They are sometimes considered to be the last line of defense, which comes into play only after rather severe erosion has taken place on the beach in front of the bulkhead. Pilings are the usual form of construction; pilings of wood, steel, and reinforced concrete are frequently used.

The present bulkheads under or alongside the boardwalk of Ocean City represent a standard use of bulkheads in shore front areas. In fact, the forthcoming Corps of Engineers' plans will probably include a bulkhead along the boardwalk area of the shore. The depth to which the bulkhead pilings are to be driven is important as the assumption must be made that a substantial portion of the sand against the seaward face of the bulkhead will be eroded away by wave action during a severe storm. Also, the seaward toe of bulkheads are sometimes protected by quarry rock of sufficient size to prevent complete undermining and collapse of the bulkhead during severe storm wave attack. One of the Corps of Engineers alternatives will probably be a bulkhead with quarry rock protection at the toe and sand fill in front of the bulkhead.

For the interim needs of Ocean City, a sheet pile bulkhead driven along the seaside or landside of the boardwalk should be considered. Due to the difficulty of placing quarry rock to protect the seaward toe of the bulkhead, this feature could be omitted from the interim plan and the piling driven to a deeper elevation to compensate somewhat for the lack of toe protection. Some form of tiebacks should be incorporated in the plan to prevent the wall falling seaward in event of severe loss of sand from the seaward face of the wall.

The top elevation of the piling should be about +14 feet MLW (the elevation of the present boardwalk), and the piling should be carried at least to MLW and very possibly to a deeper elevation to guard against undermining of the bulkhead. The placing of additional sand in front of the bulkhead would be deferred in view of the fact that the bulkhead plus the sand mass on the existing beach would probably be sufficient to protect against a 10-year storm. However, when the sand mass seaward of the bulkhead and above the mean low water line decreased in cross-section to less than 1100 sq. ft., steps should be taken to rebuild the shore to at least the 1200 sq. ft. cross-section.

The bulkhead plan would be most obviously suited to the boardwalk frontage but could be adapted to the several miles of beach between the north end of the boardwalk and the Maryland-Delaware line. Along these sections of the shore, the bulkhead would be located about 175 feet to 200 feet shoreward of the existing mean low water. Adjustment of the bulkhead line could be made to fit local conditions although gross irregularities in the bulkhead location should be avoided.

Advantages of this plan are:

1. There would be very little disturbance of the existing beach uses.

2. First cost would be much lower than the costs of a number of the other possible plans.

3. Maintenance costs of the bulkhead would be low, presuming that the bulkhead was constructed of material of suitable strength and durability. Reinforced concrete piling is probably a suitable candidate for this adaptation.

4. Some of the frontage in the boardwalk area may already be protected by a bulkhead of sufficiently rugged design so that new bulkhead construction along these frontage sections would not be required.

5. The present shore processes in the area would not be disturbed, thus the action would not have an adverse effect on Assateague Island.

Disadvantages of this plan are:

1. The bulkhead alone would not prevent further degradation of the beach in front of Ocean City.

2. If steel sheet piling were selected for the bulkhead construction material, coatings would have to be applied and aggressively maintained on any exposed portion of the steel.

3. The plan does not fit well into the probable Corps of Engineers plan except for the boardwalk area.

4.3.6 Partial Bulkhead Plan

This plan would be identical to the preceding plan except that the bulkhead would be constructed only as needed. In this plan, the bulkhead line for sections north of the boardwalk would be selected and monumented. Whenever, in a section of beach frontage, the beach cross-section seaward of the bulkhead line and above the mean low water line becomes less than 1500 square feet, then the bulkhead would be constructed along that frontage. In this way, the bulkhead would be constructed only in those sections having an immediate need for the protection. The possibility exists that in this way the Corps of Engineers plan might be put under construction before substantial lengths of the bulkhead were constructed.

The advantages of this plan are the same as for the preceding plan, plus the following:

1. Only those sections of the bulkhead most needed would be constructed before the Corps of Engineers plan was undertaken.

The disadvantages of this plan are the same as for the preceding plan, plus the following:

1. A degree of alertness on the part of the public officials would be needed in order to detect promptly any new beach frontage which needed bulkheading.

2. A flexible budget would be required to ensure that new bulkheading needs would be promptly funded.

4.3.7 Use of Seawalls

Seawalls are similar to bulkheads except that seawalls are placed lower on the beach face and are designed to come under wave attack on a daily basis and under severe wave attack during each storm. Seawalls are, therefore, much more massive structures than bulkheads and, as a result, are very much more costly to build. Costs of from $2,000 to $10,000 per front foot are to be expected in seawall construction. Examples of seawall construction are the Galveston seawall to defend against Gulf hurricanes and the seawall at Presidio Beach near San Francisco.

In view of the very expensive nature of seawalls, no detailed discussion and no plan will be described in this report as they are not likely candidates for use at Ocean City as an interim measure. Also, a seawall, when placed at or near the mean high water line - as they frequently are, greatly restricts the amount of usable beach area with easy access to the water.

4.3.8 Use of Revetments

Revetments can be thought of as blankets placed in the dry section of the beach to protect the upper sections of the beach from wave erosion during storms. Revetments are of two types:

- Rigid revetments - usually large concrete slabs placed or cast directly on the beach, or

- Flexible revetments - loose quarry stone or some type of flexible construction such as interlocking concrete blocks.

Revetments are more commonly used in semi-protected areas, such as in bays or estuaries; however, there are examples of their use on oceanfront beaches. Revetments are particularly vulnerable to being undermined at the toe (the foot) of the revetment. Thus, it is usually necessary to provide some type of cutoff wall to protect the toe of the revetment.

Many types of flexible revetments have been introduced into the market in the past few years. Some of these utilize special shapes of interlocking concrete blocks. Other use special concrete shapes glued to a plastic filter cloth. The plastic filter cloth is a special plastic fabric with holes through the plastic which are too small to permit the passage of sand but large enough to permit the rather free movement of water through the cloth.

A revetment for Ocean City could be visualized as a blanket along the entire beach front (except when bulkheads are already in place) and extending from about the mean high water line (+3.5 MLW) up to about the +10.0 MLW elevation. On a 1:15 slope, this revetment would have a width 97.5 feet (say 100 feet). The revetment could be a rigid concrete pavement or one of the flexible types of revetment. A flexible revetment of "Gobi" blocks fixed (glued) to a plastic filter cloth would be a candidate for the flexible type revetment. Both types would require a cutoff wall to protect the toe of the revetment. The cutoff wall could be of wood, steel, or reinforced concrete sheet piling. The steel piling would have to be maintained with a protective coating whenever it became exposed on an continuing basis to the atmosphere.

All beach revetments (except quarry stone) have the aspect of not being able to localize a failure. Thus, if for some reason there is a local failure, this failure tends to spread quickly throughout the entire area. Therefore, it is usually advisable to compartmentize the revetment by a system of cut-off walls extending down into the underlying sand. These walls would be designed to restrict the spread of a failure to its own compartment.

Another negative feature of revetment, in addition to the one just mentioned, is the fact that the surface of the revetment is usually so hard or rough that it would not be used for sunbathing or relaxing on the beach. Of course, it would be possible to place the revetment on a steeper slope than the normal beach slope and then cover the lower part of the revetment with sand. The lower portion of the revetment would not then be exposed until storm waves eroded the sand cover and brought the revetment into play as a protective device.

Advantages of this plan are:

1. The normal shore processes are not disturbed to any great extent by the presence of the revetment.

2. The initial cost of construction would be significantly less than some other methods of shore protection.

3. The loss of sand from the upper beach face is greatly reduced by the revetment; the need for periodic replenishment of sand to the upper beach face would be greatly lessened.

Disadvantages of this plan are:

1. The revetment is vulnerable to rapid spreading of damage and failure unless frequent containment walls are provided.

2. The surface of the revetment is not adapted to ordinary beach uses unless provisions are made to cover the revetment with sand.

3. The revetments do not protect the back shore from damage during major storms.

4.3.9 Use of Intermittent Revetments

This plan would be similar to the previous plan using revetments except that revetments would be constructed only along the beach fronts most needing protection. This plan would involve first laying out a "holding"line along the crown of the beach. This holding line would be the line where it was desired to defend against moderate storms (10-year or maybe 20-year storms). Then, whenever the beach cross-section seaward of this line and above the mean low water line became less than 1500 square feet, a revetment would be placed on this section of the beach. Wingwalls to prevent flanking of the revetment would be a feature of this plan.

Advantages of this plan are essentially the same as the previous full revetment plan, plus the following:

1. Only those sections of revetment most needed would be constructed before the Corps of Engineers plan was undertaken.

Disadvantages of this plan are essentially the same as for the full revetment plan, plus the following:

1. A degree of alertness on the part of the public officials would be needed in order to detect promptly any new beach frontage which needed revetting.

2. A flexible budget would be required to ensure that the need for new revetments would be promptly funded.

3. Adequate wingwalls would be needed at the ends of the sgements of revetment to ensure that the material is not lost from behind the segments when under storm wave attack.

4.3.10 Use of Segmented Off-Shore Breakwaters

The use of an off-shore breakwater parallel to the shore should be considered. A continuous breakwater would not be suitable because it would completely eliminate the wave action on the beach. This would rob the users of the attractive feature of the light surf breaking on the beach. This, plus the very high cost of off-shore breakwaters capable of withstanding wave atack, make the use of a continuous off-shore breakwater an impractical method of protecting the Ocean City beaches. It might be possible, however, to develop a more reasonable plan by using segmented breakwaters.

Segmented breakwaters are short sections of breakwaters placed at such a depth that the ordinary shore processes are changed by the presence of the segments. Such breakwaters are sometimes referred to as detached breakwaters. These breakwater segments affect the shore in two ways:

- They create shore compartments which tend to retain the sand within each compartment.

- They intercept a portion of the wave energy; thereby lessening the wave energy - and wave erosion capability - of the waves reaching the shore.

There is still a substantial residual of waves reaching the beach in this type of protection where beach users would not be deprived of the enjoyment of swimming in the surf. However use of the shore for surfboard riders would probably be eliminated.

Segmented breakwaters permit a certain length of the wave crest to pass between the segments and move on toward the shore. These sections of the wave crest are then diffracted as they tend to bend into the area protected by the breakwater segments. Thus, the wave crests reach the shore in a curved arc which tends to reshape the beach in a succession of cusps. In doing this, however, the waves lose their ability to transport the sand along the shore face in a continuous stream; instead, the sand tends to remain in its own compartment. Examples of segmented beach projects are to be found at Deerfield Beach, Florida; Presque Isle Park, Erie, Pennsylvania; and Monte Carlo, Monaco.

For a plan suited to Ocean City, the segments would be placed in about six feet of water. The breakwaters could be built as rubble mound structures or as caisson-type structures. In any event, the breakwater segments would have to be of rugged construction, designed to withstand the force of the full-sized storm waves which could reach the structures.

The advantages of this plan are:

1. The erosion attack of the waves on the shore would be greatly reduced.

2. There would be comparatively little sand lost from the nearshore and beach area even during storms of considerable magnitude.

3. Surf conditions would be reduced, but not eliminated, on the Ocean City beaches; thus surf bathing could be enjoyed more days per year than at present.

4. Yearly maintenance costs would be low if the breakwaters were properly designed and constructed.

The disadvantages of the plan are:

1. There would be very little sand moving south past the present north jetty which could ultimately reach the eroding shores of Assateague Island. The blocking of the sand would have a beneficial effect on the inlet navigation channel.

2. The first costs would be rather large.

3. The structure would benefit the probable Corps of Engineers plan but would not be an essential part of this Corps plan.

4.3.11 Use of Novel Breakwater Units

There have recently been put forward several novel types of breakwaters which should be discussed with reference to Ocean City. One of these are the floating tire breakwaters made by tying or bolting together old automobile tire casings in certain configurations and then anchoring these floating mazes offshore. Here they act to reduce the wave heights and thereby reduce the shore erosion potential of the waves. These floating tire units have been tested in relatively sheltered water (waves not over 4 to 6 feet in height) in several locations. While these units do reduce the wave heights somewhat, no way has yet been devised to prevent them from breaking apart or keeping them anchored in strong wave action. Thus, it does not appear that these units have any applicaton on the Ocean City beach.

Other types of preformed units have been proposed and tested to a certain extent. One of these is a Z-wall unit composed of Z-shaped concrete units standing vertically and bolted together to form a length of breakwater. They have not proven stable under wave action on the Great Lakes where the wave climate is not as severe as at Ocean City. Thus, they would seem to have no application at Ocean City.

Another unit know as the "Shorprotector" consists of a series of steel slats, with spaces between, mounted on a triangular shaped steel A-frame. The units are about six feet in height, base to apex of triangular frame, and are fabricated ashore and then placed off-shore by helicopter. Trials of the "surf-breaker" concept at Virginia Beach, Virginia, showed them to be unsatisfactory for use on open ocean beaches.

The novel unit showing the most promise at present is a patented device called a "Longard Tube". It is a plastic tube 4 or 6 feet in diameter and about 100 yards in length. The tube is pumped full of sand while being held at its intended site. The unit can be placed offshore in shallow water to reduce wave action or at the base of a bluff to defend the toe against wave action. These Longard Tubes have not been sufficiently tested for strength and stability in heavy wave action to warrant recommending them except on an experimental basis. One grave weakness is their susceptibility to vandalism or to puncture by floating debris; this weakness has been shown at a few of the experimental test sites.

4.3.12 Use of Sand Back-Passing

By the term "sand back-passing" is meant a system which traps the sand at the down-drift end of a littoral drift compartment

In the case at Ocean City, this would mean, under present conditions, trapping the southward moving littoral drift at the north jetty and then, in some way, transporting this sand nine miles north and placing it on the Ocean City beach near the Delaware line. The present estimate of southward moving littoral drift passing the north jetty is in the order of 150,000 yd^3 per year; thus, a sand back-passing arrangement would be expected to resupply 150,000 yd^3 or so to the beach front of Ocean City.

Actually, the analysis on Table 2 shows that the present rate of loss (1965 to 1979) from the shore between the mean high water line and the - 20-foot contour is 308,000 yd^3 per year, or about twice the 150,000 yd^3 of the possible sand back-passing rate. Therefore, while sand back-passing would be helpful it would not be the complete solution to the long-term shore erosion problem at Ocean City.

This sand placement could contribute to decreasing the rate of erosion and possibly serve as a sufficient measure during the interim period until the Corps' program is undertaken. This optimism is justified to a certain extent by the fact that the sand losses between the mean high water line and the - 10-foot contour for the northerly eight miles of the shore averaged only 113,500 yd^3 per year for the recent 14-year period. Thus, if the 150,000 yd^3 available for back-passing was placed at the more critical sections of the beach from year to year, the present erosion tendency could possibly be checked or certainly decreased.

There are two difficulties with this plan of back-passing: First, back-passed sand would have to be pumped, or otherwise transported, a distance of eight or nine miles, and second, the permanent denial of this sand to Assateague Island might cause some difficulty from a legal and environmental standpoint.

It is to be recognized that the placement of 150,000 yd^3 per year over the northerly seven or eight would not be expected to widen the beach or make it better able to withstand storm wave attack. The most that could be expected from this treatment would be to hold the beach front in its present position and condition. Of course, if a separate sand supply was used to rebuild the beaches as outlined above, the back - passed sand could be used to maintain the replenished beaches as previously discussed.

Advantages of this plan are:

1. It would possibly maintain the beaches in their present position unless a major storm struck the area;

2. It would not interfere with present uses of the beaches;

3. Maintenance of the inlet navigation channel would be made easier.

Disadvantages of this plan are:

1. It would not significantly improve the present condition of the beaches;

2. The sand transportation costs from the inlet to the northerly few miles of beaches might be rather high due to the distance involved;

3. The sand would permanently be denied to Assateague Island, and this might create certain legal and environmental problems.

4.3.13 <u>The Use of Sand Bulldozing</u>

The effect of bulldozing sand from the lower portions of the dry beach to the upper portion is to gain an additional hour or two of initial protection against the next storm. Frequent recurrences would make this type of protection rather expensive, and if the interval between storms was too short, there would not be time to bulldoze sand up on the beach. Also, if the storm was of such a duration that storm waves and high tides coincided for a period of about five hours or more, the effect of the bulldozing would probably not be significant.

The above, in effect, says that if the storm's waves lasted only through one high tide, there would be some benefit from the bulldozing, but if the storm lasted through two high tides the effects of bulldozing would probably not be significant. A study of probable storm durations at Ocean City would be needed to enable the relation between costs and benefits to be established relative to sand bulldozing. A study of storm durations at Ocean City was not available at the time of this preliminary report.

5.0 PERTINENT STATEMENTS

In arriving at the analyses and developing the plans given in this preliminary report, the assumption has been made that the data made available to the writers was sufficiently accurate for use in the analyses. In view of the scope of the study, no attempt was made to check the accuracy of the basic data as long as the data was from a seemingly reliable source.

Another factor of concern is the long-term and short-term implications of the significant deepening of the waters close in-shore at Ocean City. This eroding condition is discussed previously in this report. The analysis and discussion show that there has been a massive loss of sand from the in-shore waters (inside the -30 foot contour) over the past 130 years which is out of proportion to the landward shift of the mean high water lines. This condition results in an increased potential for destructive erosion of the beach face during a prolonged storm. The full implications of this massive in-shore erosion, particularly erosion seaward of the -10 foot contour have not been considered in this present report as the report is directed primarily to interim measures for Ocean City. The Corps of Engineers forthcoming study can be expected to address questions of long-term tendencies and long-term solutions.

Some of the alternative plans described in this report — such as the very long groin plan outlined above — are not intended to represent interim measures. Rather, they are included to show the considerable difference between a possible permanent solution and an interim solution to the erosion problems at Ocean City.

Within this report, the details of the various alternative plans are not developed fully. More detailed development will be made of the alternatives selected for further study by CRAC and DNR.

Certain quantity calculations used in describing the alternative plans used figures based on the Corps' 1965 survey. These figures will be revised in the next phase of this report to reflect the conditions shown on the Corps' 1979 report. This 1979 report did not become available to the writers until after a considerable number of critical calculations had already been made using the 1965 survey and time has not permitted the adjustments of these figures to the 1979 survey. The revisions to utilize the 1979 survey are not expected to produce significant differences from the present report.

A P P E N D I X   A

INFORMATION SHEET - OCEAN CITY, MARYLAND

PLANS OF IMPROVEMENT FOR BEACH EROSION AND HURRICANE PROTECTION FROM OCEAN CITY INLET TO MARYLAND-DELAWARE LINE

Furnished by: U. S. Army Corps of Engineers
District Baltimore

APPENDIX A

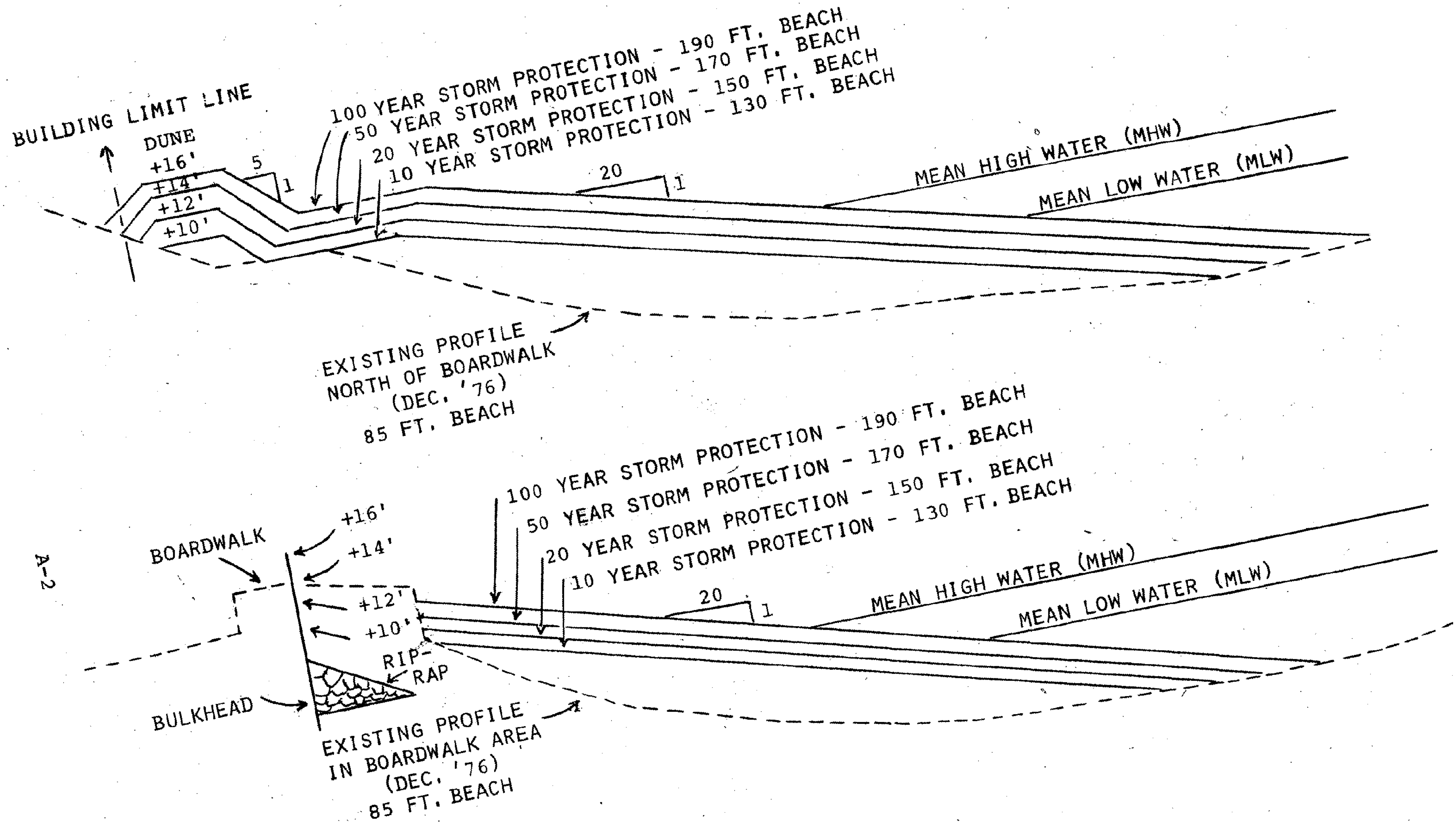
INFORMATION SHEET - OCEAN CITY, MARYLAND
PLANS OF IMPROVEMENT FOR BEACH EROSION AND
HURRICANE PROTECTION FROM OCEAN CITY INLET TO
MARYLAND-DELAWARE LINE

Furnished by: U. S. Army Corps of Engineers
District Baltimore

The alternative plans of protection for Ocean City provide for beach erosion control and hurricane protection for the 100 year, 50 year, 20 year, and 10 year storm levels. The plans considered consist of widening and raising the beach along the entire reach from 10th Street to the Maryland-Delaware line plus creating a dune line from the end of the boardwalk to the Maryland-Delaware line and constructing a steel sheet pile bulkhead from the end of the boardwalk to several blocks south of 10th Street, depending on the degree of storm protection desired. Figure 1 indicates the four plans of protection investigated.

Each widened beach will have a 50-food wide berm with the foreshore slope from the seaward edge of the berm to existing ground on a slope of 1 on 20. The wider beach will provide a larger area for recreation and also a larger area over which wind generated waves may be dissipated. A steel sheet pile bulkhead with concrete cap would be constructed on the beach side of the boardwalk. A bulkhead is recommended in this reach instead of a dune because the wide base of a dune would limit the usable recreation area. A sand dune above the level of the boardwalk would also cause clean-up problems from wind blown sand. In the event of severe scour, the bulkhead is protected by a stone revetment buried in the sand at and elevation of 4 feet above mean low water. The revetment is composed of 500 to 1000 pound stones resting on a woven plastic filter cloth.

Between North Division Street and the North Jetty, the beach is of sufficient width to dissipate wind generated waves, therefore, the bulkhead or beach fill is not required in this section.



ALTERNATIVE PLANS OF PROTECTION

Figure 1

The centerline of the dune construction from 27th Street to the Maryland-Delaware line will be located 25 feet east of the Building Limit Line. The dune crest would be 25 feet wide with the sideslopes of 1 on 5. A slat type sand fence will be established on the crest of the dune to catch wind-blown sand, affording an even higher degree of protection, and to prevent human traffic from crossing the dune at unspecified points. The dune will be stabilized by beachgrass.

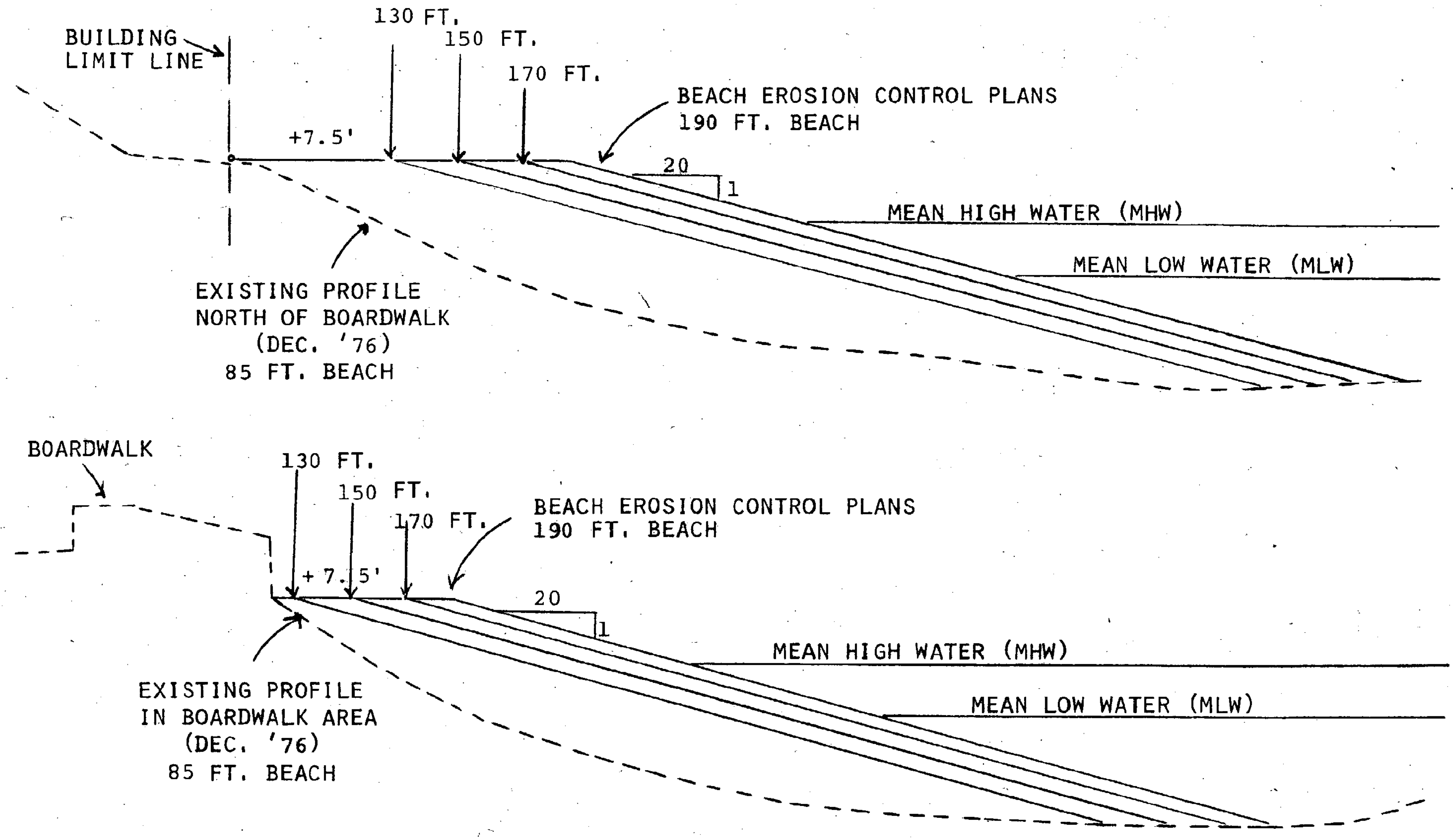
These combined beach erosion control and hurricane protection sections will provide a minimum beach width of about 190 feet, 170 feet, 150 feet, and 130 feet for the 100 year, 50 year, 20 year, and 10 year storm levels, respectively, between the bulkhead or the seaward toe of the dune and mean high water.

In addition to these four plans of protection, four plans that would provide only for erosion control (no storm protection) were investigated. Figure 2 indicates the four plans investigated. These plans will not include dunes or steel sheet pile bulkheads for storm protection but will consist of beach widths of 190 feet, 170 feet, 150 feet, or 130 feet.

Because the natural wave and storm action at Ocean City will continue to erode and remove sand from the beaches even after construction of one of the eight plans described, it will be necessary to periodically nourish or replace this sand from an outside source. This quantity is currently estimated to be 100,000 c.y. per year. Periodic nourishment would be accomplished every two to three years. In order to reduce the annual cost of this periodic nourishment, insure a supply of suitable beachfill for nourishment, and prevent any of the eroding beachfill from shoaling in the inlet a deposition basin and a weir-jetty extension to the north jetty will be construction *(sic)*. The function of this system is shown on Figure 3 and described in Inclosure 1.

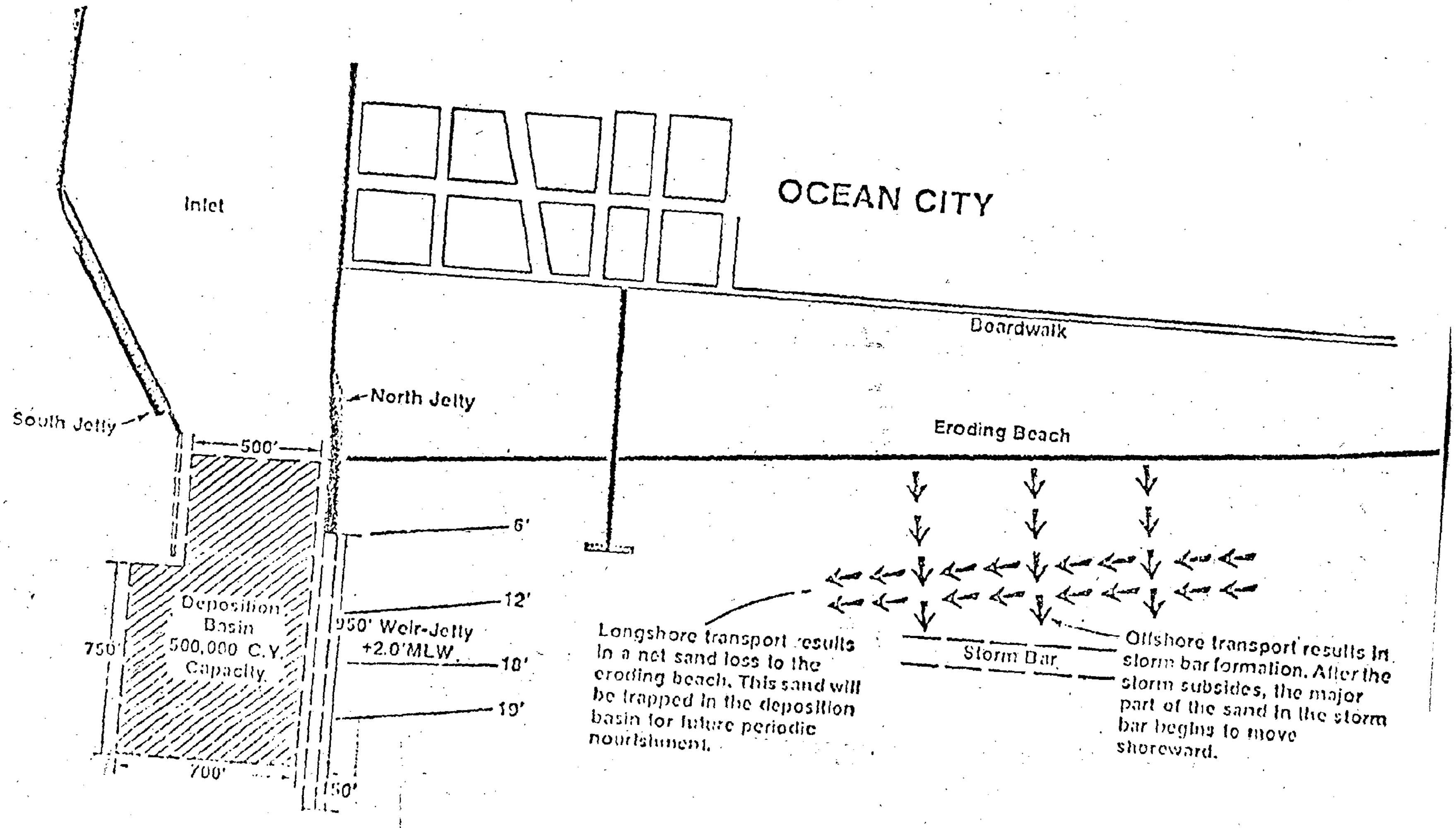
In addition to periodic beach nourishment, fertilization and replacement of dune grasses, and bulkhead maintenance is required. Table 1 indicates the first costs and maintenance costs of each of the eight plans considered. These costs are broken down into a Federal share and a non-Federal share and are based on March 1977 price levels.

Note: Source of beachfill is an offshore shoal area located just south of the south jetty and about 1/2 mile offshore.



BEACH EROSION CONTROL PLANS

Figure 2



STORM EROSION

Figure 3

17 March 1977

TABLE 1

OCEAN CITY, MARYLAND

BEACH EROSION CONTROL - HURRICANE PROTECTION

	Hurricane Protection and Erosion Control *				Erosion Control *			
	100 year	50 year	20 year	10 year	190 feet	170 feet	150 feet	130 feet
Benefit-Cost Ratio	7.3/1	7.6/1	7.7/1	7.8/1	9.9/1	9.9/1	9.7/1	9.6/1
Annual Benefits	14,480	13,347	11,942	10,354	12,934	12,017	10,844	9,561
First Costs								
Federal	14,151	11,961	9,891	7,889	6,485	5,822	5,063	4,184
Non-Federal	7,917	6,790	5,685	4,577	6,485	5,822	5,063	4,184
Annual Costs								
Federal								
Interest and Amortization	945	799	661	527	433	389	338	280
Maintenance	110	110	110	110	220	220	220	220
Non-Federal								
Interest and Amortization	529	453	380	306	433	389	338	280
Maintenance	394	392	390	389	220	220	220	220

* ALL COSTS SHOWN ON THIS SHEET ARE IN $1,000

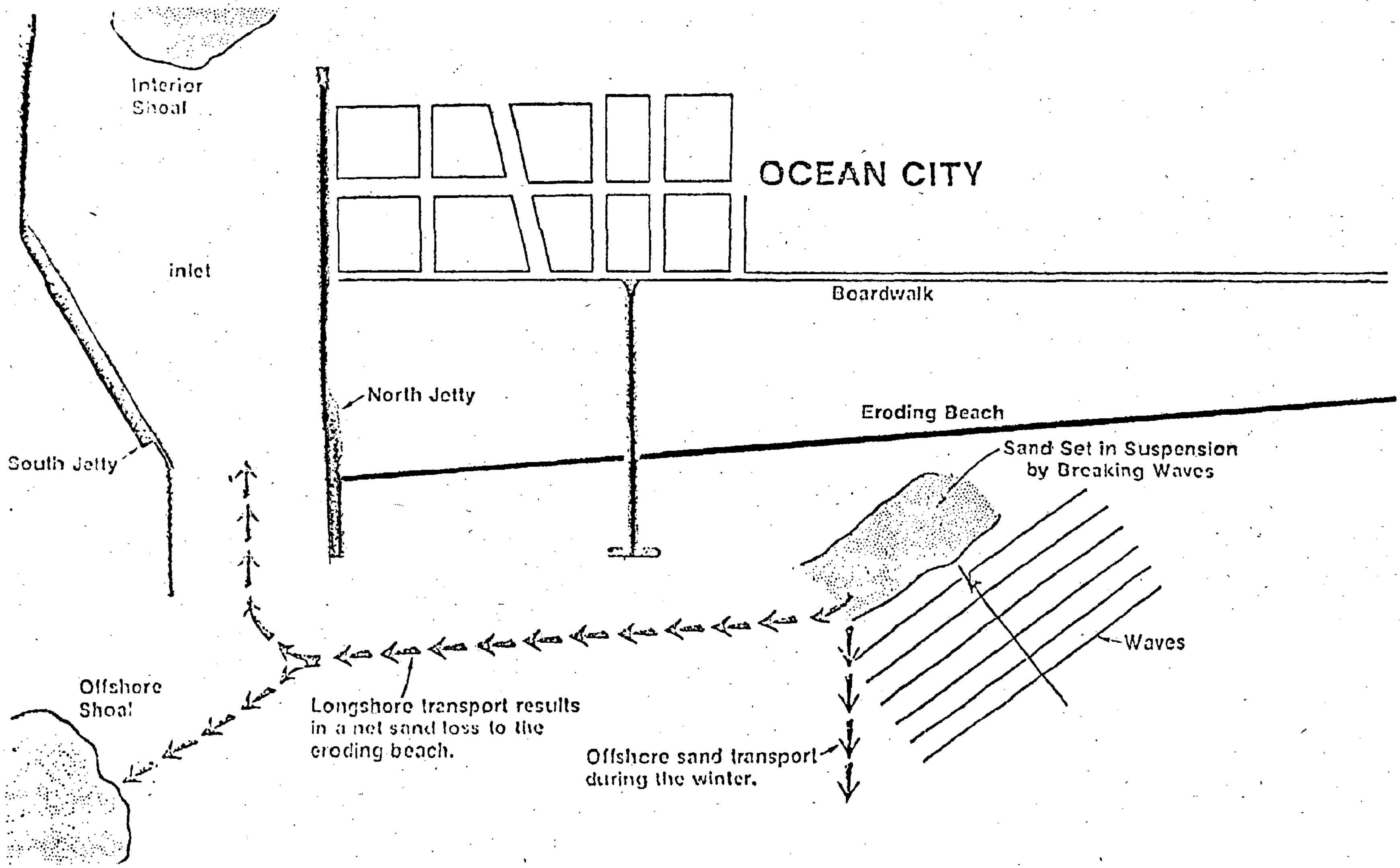
SAND BACK-PASSING/BY-PASSING SYSTEM AT OCEAN CITY INLET

Waves arriving at an angle to a shoreline generate a longshore current which picks up sand set in suspension by the breaking waves and carries this sand along the shoreline (longshore transport) to nourish downdrift shoreline segments. Upon reaching an inlet, the tidal forces of the inlet interrupt the longshore transport and results in the sand in transport 1) entering the inlet and forming interior shoals 2) being jetted offshore and forming an offshore shoal and 3) naturally by-passing the inlet to nourish the downdrift shoreline. If processes 1) and 2) predominate, then, severe erosion will occur on the downdrift shore adjacent to the inlet. Stabilization of an inlet by jetties increases the interruption of the longshore transport by causing sand to accumulate on the updrift side of the updrift jetty, at least until this area fills to capacity and the normal processes described above resume.

In order to avoid adverse shoreline erosion downdrift of a jettied or unjettied inlet, mechanical sand by passing can be utilized. This process simply involves obtaining an amount of sand equal to that being transported along shore updrift of the inlet and depositing this amount of sand on the shoreline downdrift of the inlet thus re-establishing the longshore transport system. Sources of sand for by-passing are usually 1) inlet interior shoals 2) inlet ocean shoals or 3) sand that is trapped by the inlet jetties.

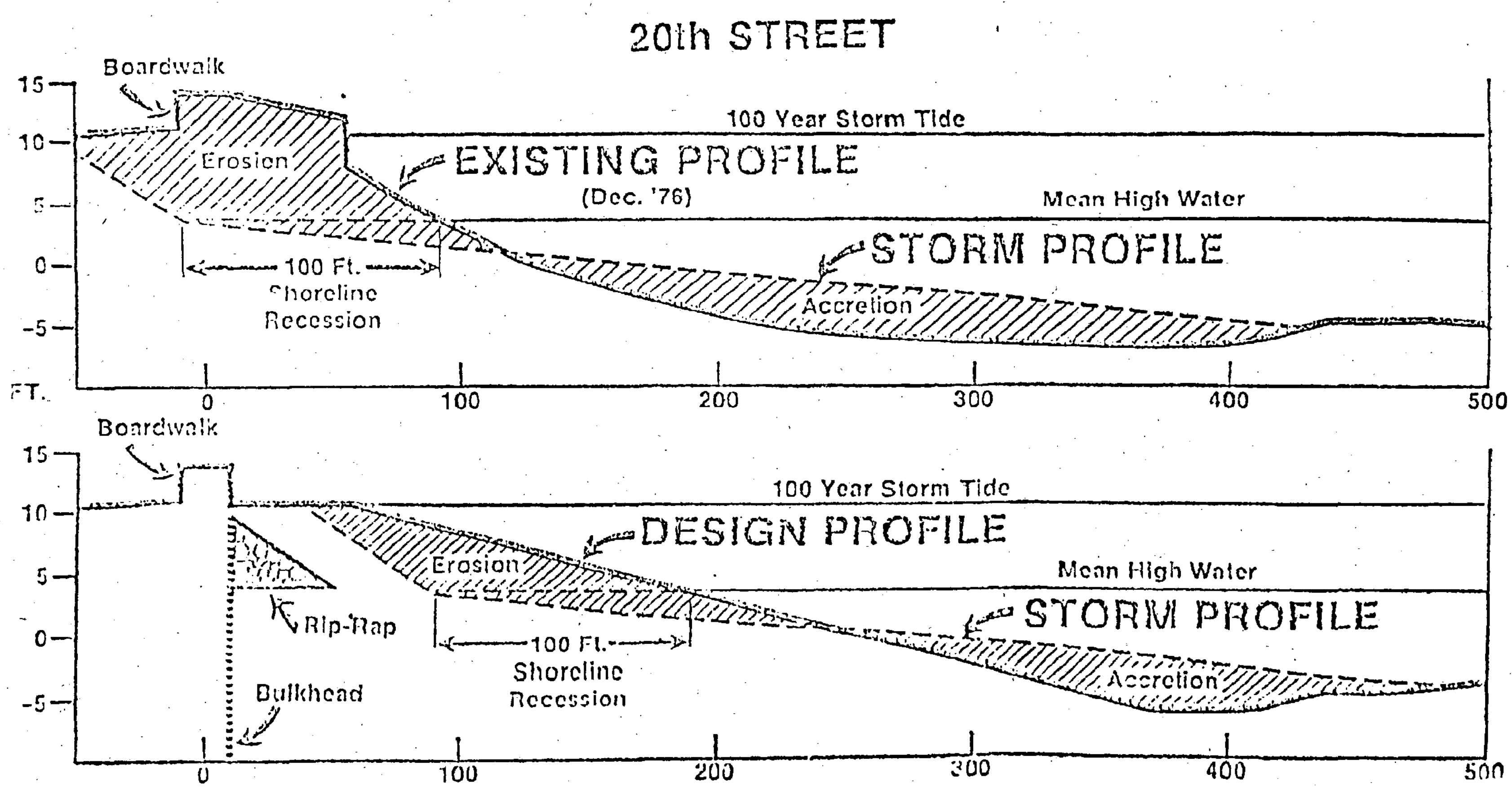
It is evident that Ocean City Inlet and its stabilizing jetties (particularly the North Jetty) is interferring with the longshore transport system along the shoreline of Ocean City, Maryland, and Assateague Island, Maryland, and has resulted in the shoreline recession of the Northern end of Assateague Island. As part of the Baltimore District's recommended plan of improvement for Ocean City, Maryland, in the interest of erosion control and hurricane protection, an 1,100 foot weir-extension to the North jetty is being proposed along with a 500,000 c.y. deposition basin as shown on Figure 3. The purpose of this system is to trap sand eroding from Ocean City's beaches for use as periodic nourishment to maintain the beaches after they are widened by an initial beachfill operation. This system operates as a "back-pass" system in that sand will be re-cycled along Ocean City's beaches. The periodic nourishment requirements for Ocean City's beaches is estimated at 100,000 c.y. per year. Since the annual filling rate of the deposition basin is estimated to be greater than 100,000 c.y. per year, there is the potential for sand being available for by-passing to the Northern end of Assateague Island.

Accordingly, in the engineering plan developed for erosion control and hurrican protection for Assateague Island for the National Park Service, it is recommended that sand be by-passed from the deposition basin to the Northern end of Assateague Island to accomplish a portion of the periodic nourishment requirements for Assateague Island. In the event the engineering plan for Assateague Island, as developed by the Corps of Engineers for the National Park Service, is not authorized and constructed, but the Ocean City plan is authorized and constructed with the weir-jetty and deposition basin, an amount of sand should still be available for periodic by-passing to Assateague Island if desired. Detailed study is needed to determine that actual amount of sand that will be available.



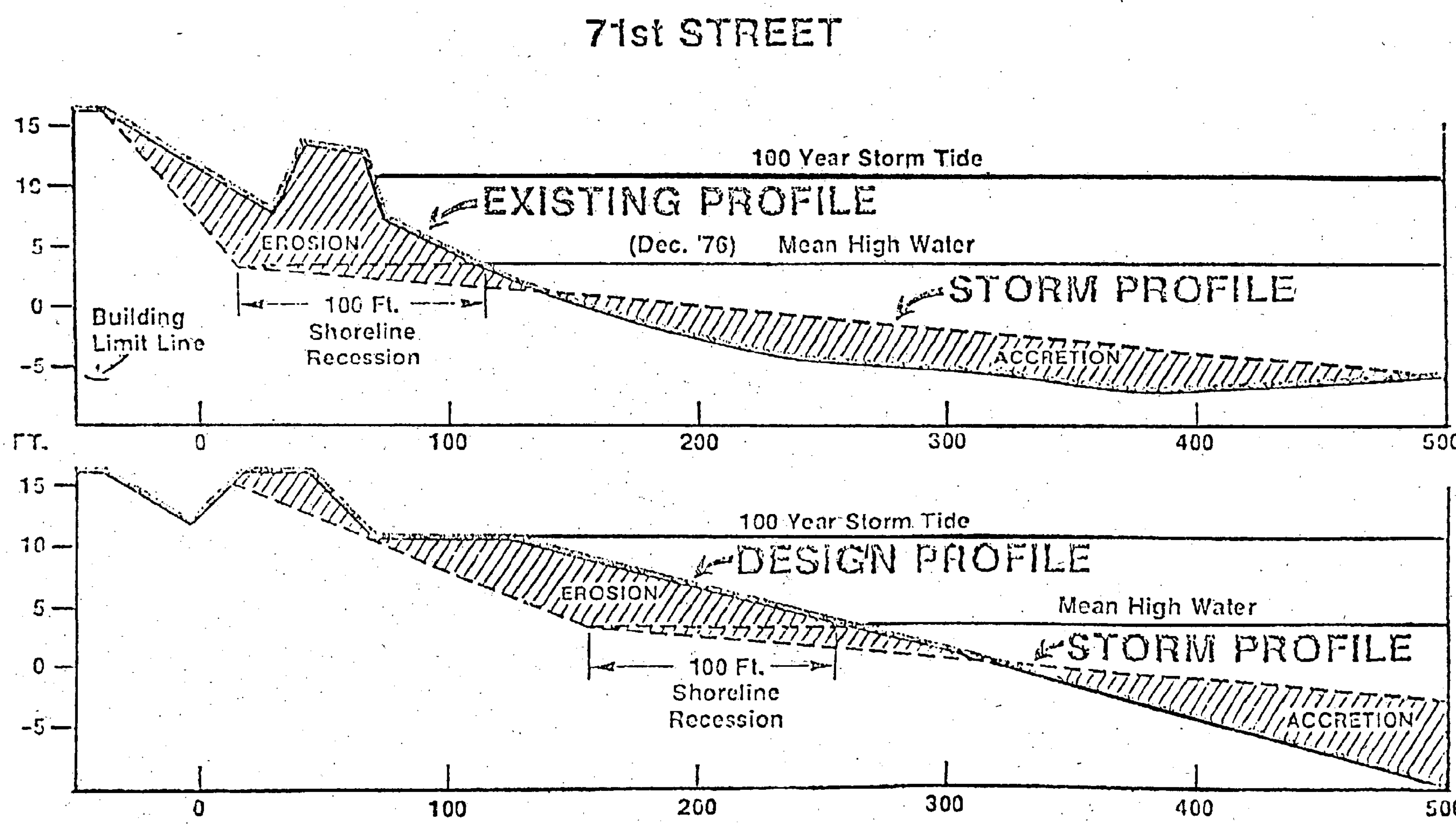
SAND TRANSPORT

Figure 4



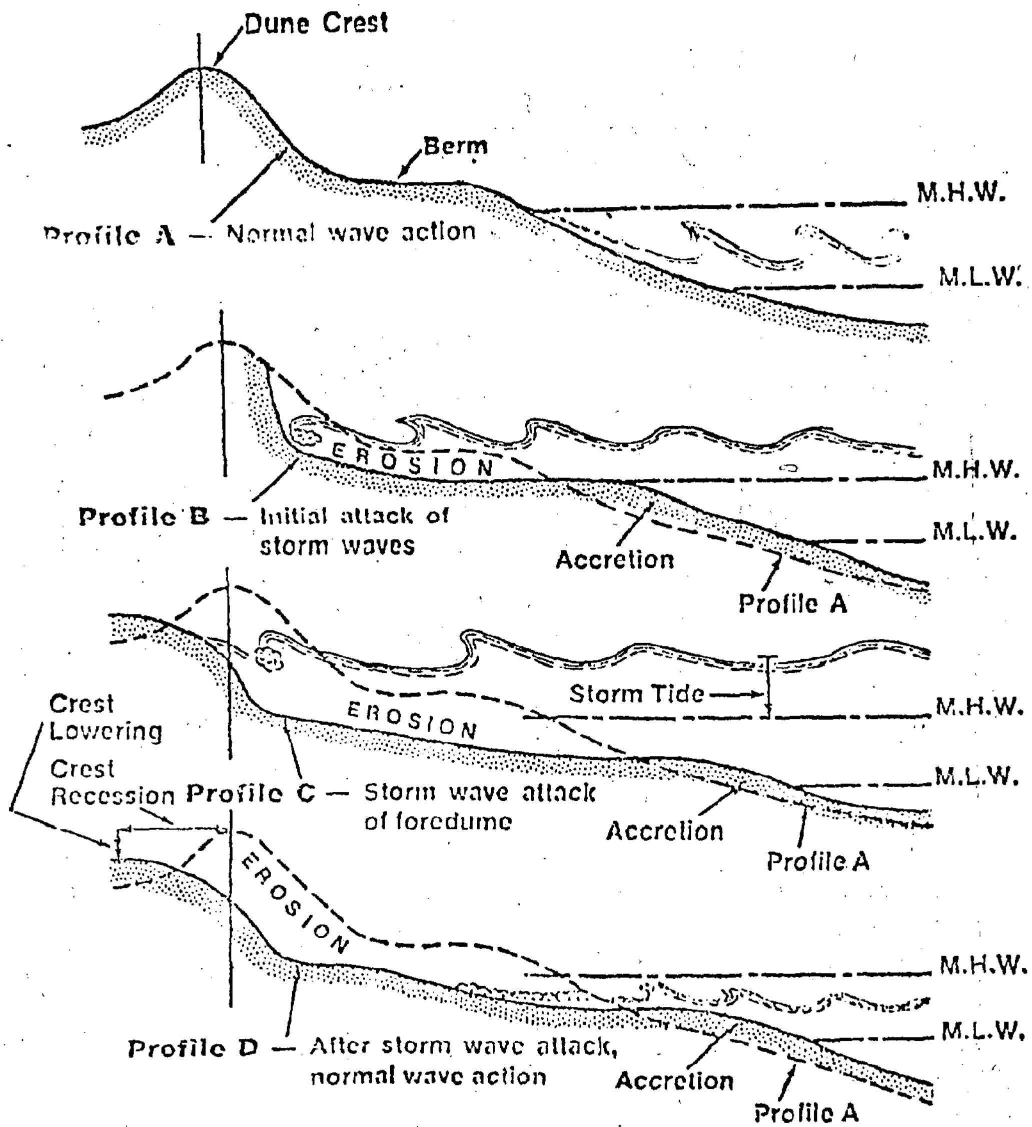
STORM EFFECTS ON EXISTING AND DESIGN PROFILES

Figure 5



STORM EFFECTS ON EXISTING AND DESIGN PROFILES

Figure 6



SCHEMATIC DIAGRAM OF STORM WAVE ATTACK
ON BEACH AND DUNE

Figure 7

A P P E N D I X   B

EXCERPTS FROM THE

SHORE PROTECTION MANUAL, VOLUME II

U. S. ARMY COASTAL ENGINEERING RESEARCH CENTER

1977, Third Edition

APPENDIX B

The following are excerpts quoted from the Shore Protection Manual, Volume II, U. S. Army Coastal Engineering Research Center, 1977, Third Edition.

"5.6 GROINS

5.62 DEFINITION

A groin is a shore protection structure designed to build a protective beach or to retard erosion of an existing or restored beach by trapping littoral drift. Groins are usually perpendicular to the shore and extend from a point landward of predicted shoreline recession into the water far enough to accomplish their purpose. Groins are narrow, and vary in length from less than 100 feet to several hundred feet. Since some of the littoral drift moves in the zone landward of the normal breaker zone (for example about the 6-foot contour on the Atlantic coast), extending a groin seaward of that depth is generally uneconomical. The normal breaker zone for the Gulf coast and less exposed shores of the Great Lakes ranges from 3- to 4-foot depths; more exposed shores of the Great Lakes approach the 6-foot depth. The Pacific coast ranges from 7- to 10-foot depths depending on exposure."

"5.65 GROIN OPERATION

The typical groin, illustrated in Figure 5-8, extends from a point landward of the top of the berm to the normal breaker zone (for instance, the 6-foot depth contour on the Atlantic coast). The predominant direction of wave attack shown by the orthogonals will cause a predominant movement of littoral drift."

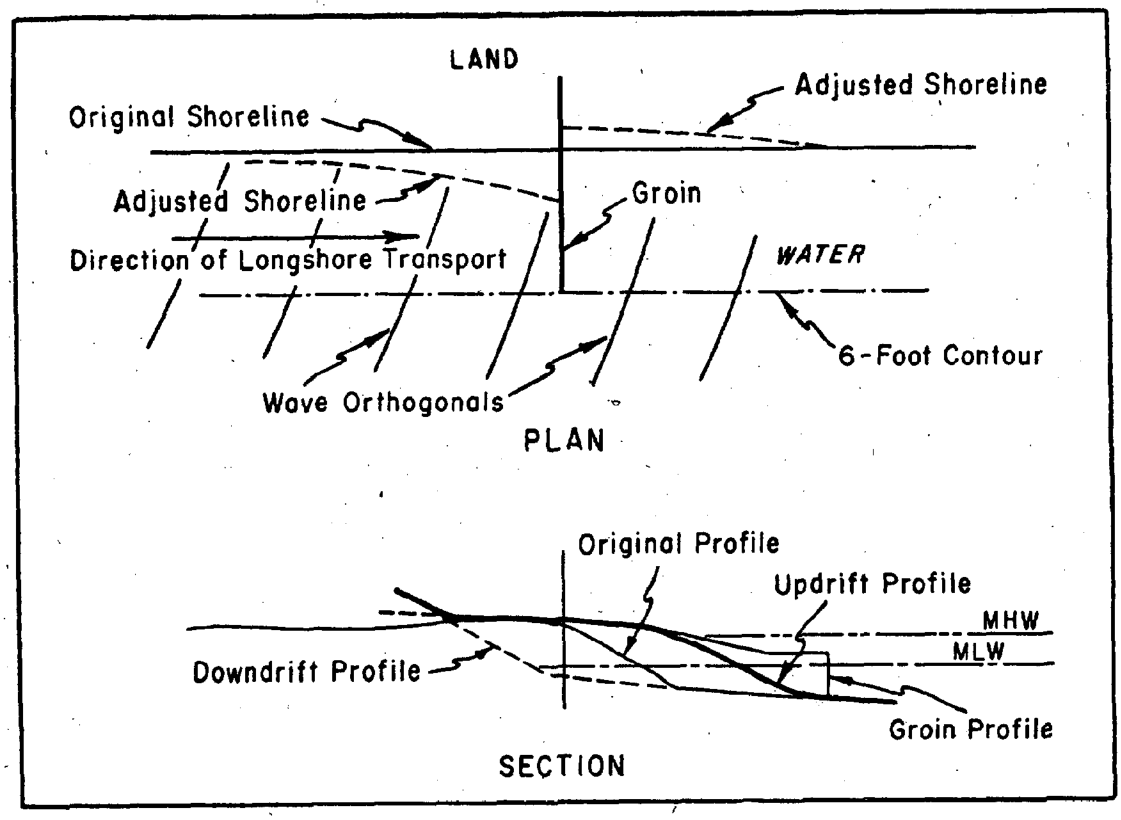


Figure 5-8. Illustration of a Typical Groin

"5.66 DIMENSIONS OF GROINS

The length of a groin is determined by the distance to depths off-shore where normal storm waves break, and by how much sand is to be trapped. The groin should be long enough to interrupt enough material to create the desired stabilization of the shoreline or accretion of new beach areas. Damage to downdrift shores must be considered in determining the groin length. For functional design purposes, a groin may be considered in three sections: (a) horizontal shore section, (b) intermediate sloped section, and (c) outer section."

"5.664 Spacing of Groins. The spacing of groins in a continous system is a function of the length of the groin and the expected alignment of the accretion fillet. The length and spacing must be so correlated that when the groin is "filled to capacity, the fillet of material on the updrift side of each groin will reach to the base of the adjacent updrift groin with a sufficient margin of safety to maintain the minimum beach width desired or to prevent flanking of the updrift groin. ...*As a guide to the spacing of groins, the following general rule is suggested: The spacing between groins should equal two to three times the groin length from the berm crest to the seaward end.*"

Section II
pages 1-22

SUMMARY SHEET FOR COSTS FOR ALTERNATIVE METHODS OF BEACH RESTORATION AND MAINTENANCE

This summary sheet has been prepared for use by the Coastal Resources Advisory Committee (CRAC) group in selecting the two or three beach restoration plans to be studied in greater detail by Trident in the final phase of the project. The details for the alternative methods of beach restoration are contained within Trident's preliminary report, "Interim Beach Maintenance at Ocean City", pages 44 to 77. Each alternate method is referenced to the specific page in the preliminary report. Costs are expressed in 1978 dollars with no allowance for inflation. They can be considered as relative figures only.

A. Sand Replenishment

This method implies the pumping or hauling of sand of proper grain size to the beach face from an "outside source". Possible sources are off-shore deposits or from Ocean City Inlet or bays if sand is of proper grain size. *(Reference: Page 44 of Preliminary Report.)*

- Quantity — Requirement for initial beach profile of a minimum 30-foot berm width is 1.5 to 2.0 million cu. yd. Annual replenishment estimated to be 150,000 to 225,000 cu. yd./year.

- Costs — The cost for hydraulic dredging is estimated to be approximately \$4.00/cu.yd. which is based on the latest (1978) costs incurred by the Corps of Engineers for dredging 60,000 cu. yds. from the Ocean City Inlet with a 12" section line dredge, piped 3/4 mile distance, and placed on Assateague Island. Large volume dredging has been bid at lower costs to the Corps, ranging from \$1.77 - \$.77 cu. yd. for quantities in the range of 3.5 to 1.5 million cubic yards. However, it should be noted that the costs per cubic yard are entirely dependent upon the source of the material and the distance that it is to be pumped or hauled.

  - Initial Costs — 1.5 million cu. yd. @ \$4.00/cu. yd. \$6,000,000.00
  - Annual Replenishment — 150,000 cu. yd. @ \$4.00/cu. yd. \$600,000.00

- Advantages of Sand Replenishment Method

  1. It would increase the recreational beach area, and present types of beach use could be continued with very little interference.

2. It would provide a buffer to protect the backshore from damage during a moderately severe storm (a 10-year storm).

3. The plan corresponds with the probable Corps of Engineers plan as it is basically the same as the plans most seriously considered by the Corps for recommendation (see Appendix A of report).

- Disadvantages of Sand Replenishment Method

1. The plan does not protect the backshore against a storm of medium severity or greater (15-year storm or greater). This is particularly true if only the 30-foot berm width were adopted.

2. The yearly maintenance figure for new sand required to maintain the shore is uncertain. It might conceivably be much more (100% or more) than the 150,000 cu. yd./year estimate.

B. Very Long Groins

Stone groins, 800 to 1,000 feet long at one-mile intervals.

(Reference: Page 48 of Preliminary Report.)

- Quantity — Eight groins would be required for the nine miles of Ocean City beach front.

- Costs — No actual costs are available for construction of groins of this size. However, the 15th Street 80-foot stone groin extension constructed in 1978-79 at Ocean City cost the city $77,000.00 to install themselves. These cost figures were received in oral communication with Mr. Leonard M. Larese-Casanova of the Shore Erosion Control Program of DNR. The only commercial bid received for this proposed construction was for $110,000 ($110,000 for an 80-foot stone groin would be $1,375 per linear foot). It is estimated that a 1,000-foot stone groin would cost at least 2.5 times the lineal foot unit cost considering the increased cross-section widths of the groin base and a higher vertical profile that would be needed for the groin to function properly in deeper water. Using the unit cost of $1,375/lin. ft. x 2.5 as a conservation figure for the increased size, a 1,000-foot groin would cost $3,438/lin. ft. or $3,438,000. In addition, a total of 3,400,000 cu. yds. of sandfill would be need to keep the northerly end of each mile section from eroding. The cost of dredging the sand from off-shore deposits is estimated at $4.00/cu. yd. for the 3,400,000 cubic yards or $13,600,000 for dredging.

Dredging...	$13,600,000.00
Construction of eight groins...........	27,504,000.00
Estimated Total Cost....................	$41,104,000.00

- <u>Advantages of Very Long Groin Method</u>

  1. The erosion of the shore would probably be stopped or reduced to a very low rate.

  2. Maintenance costs would be low.

  3. It would increase the recreational beach area and the present types of beach use could be continued with little interference.

  4. The groins could be designed to provide recreational fishing along the outer portions.

- <u>Disadvantages of Very Long Groin Method</u>

  1. It would have a very high initial cost.

  2. It would not meld with the probable plan to be recommended by the Corps of Engineers.

3. It would permanently eliminate the passage of littoral drift past the north jetty. This could conceivably benefit the navigation channel in the inlet but has a high potential for continuing damage to Assateague Island.

C. Long Groins

Groins 400-500 feet in length constructed of wood, metal, or stone. *(Reference: Page 50 of Preliminary Report.)*

- Quantity — 32 groins would be required with a spacing of approximately four groins per mile.
- Costs — The construction of long groins would be higher in linear foot costs than the short groins presently built at Ocean City as the extra length would require working in deeper water, out to about the -6 foot contour. The latest cost figures (1978) for a 201-foot groin construction at Ocean City was $58,604.00 including engineering design ($292.00 per linear foot). Assuming a 50% increase for the longer groins in deeper water, this would amount to $438.00 per linear foot. A 500-foot groin would thus cost

approximately \$219,000. Thirty-two groins would be needed to maintain the proper spacing within the eight miles of beach in need of protection — 32 x \$219,000 = \$7,008,000. For maximum and immediate protection, the groins should be filled with sand. It would require approximately 2.0 million yd^3 to fill all eight groins. Dredging from off-shore deposits @ \$4.00 yd^3 for 2.0 million yd^3 = \$8,000,000.

Dredging...............................	\$ 8,000,000.00
Construction of eight groins...........	7,008,000.00
Estimated Total Cost...................	\$15,008,000.00

- Advantages of Long Groin Method

1. An assumed permanent solution to the shore erosion problem would result.

2. Groin maintenance costs under normal conditions would be moderate, assuming well-constructed groins.

3. Beach maintenance costs would be moderate as the groins would act to retain most of the beach sand in its own beach compartment.

4. The recreational area on the beaches would be increased and the present type of beach uses could be continued with little interference.

5. Protection against 10-year storms would be attained over all the shore face and for 25-year or greater storms for those portions of each compartment which happened to be widest when the storm struck. (Normally, this widest portion would be the southerly part of each compartment.)

6. The plan would be compatible with the Corps' probable plan.

- <u>Disadvantages of Long Groin Method</u>

1. The initial cost would be high.

2. Much of this plan might be accomplished at State expense before the Corps began work, in the event that the Corps selects the same plan.

3. The passage of littoral drift to the south past Ocean City would be essentially eliminated. This could conceivably benefit the navigation channel in the inlet, but has a high potential for continuing damage to Assateague Island.

4. A large storm (50-year storm or greater) might, in one event, pull enough material out into deep water offshore to leave the beach face again exposed to wave damage. Replacement of this sand might be necessary.

D. Short Groins

Groins 325 feet in length. *(Reference: Page 55 of Preliminary Report.)*

- Quantity — 47 groins total - 19 new groins plus extension to 325 feet to the 28 existing groins.

- Costs — Using the 1978 construction costs of $292.00 per linear foot for the 201-foot groins most recently built at Ocean City, it is estimated that a 325-foot groin would increase the linear foot cost by 15% or $336/lin.ft. For 19 new groins, this amounts to $2,074,800. Extension of 125 feet to the existing 28 groins would be approximately $1,176,000.00. To ensure proper protection to the shore front, beach fill of approximately 1.5 million cu. yds. should be added, same as for the sand replenishment method. At $4.00/cu. yd. x 1.5 million yd^3 = $6,000,000.00.

Dredging....................................	$6,000,000.00
Construction of 19 new groins............	2,074,800.00

125' extension to 28 existing groins.....$1,176,000.00

Estimated Total Cost....................$9,250,800.00

- Advantages of Short Groin Method

1. It would increase the recreational beach area, and present types of beach uses could be continued with very little interference.

2. It would provide a buffer to protect the backshore from damage during a moderately severe storm (a 10-year storm).

3. The plan would be compatible with the probable Corps of Engineers plan as it is basically the same as the plans presently receiving the most consideration by the Corps.

4. The rate of annual beach nourishment would be reduced to possibly one-half of that required under the beach replenishment plan alone.

5. The groins would reduce localized erosion fluctuations below the fluctuations which could be expected with sand replenishment alone.

- Disadvantages of Short Groin Method

1. The plan does not protect the backshore against a storm of medium severity (a 15-year storm or larger).

2. The first cost is considerably more than for the "sand replenishment alone" plan due to the cost of 28 groin extensions and 19 new groins.

3. A severe storm (25-year storm or greater return frequency) might severely erode the shore face and necessitate a massive sand replenishment program.

E. Bulkheads

Short pile bulkhead without rock toe protection for interim protection. *(Reference: Page 58 of Preliminary Report.)*

- Quantity — Variable distance, dependent upon the structures that are intended to be protected. Assume 6,100 linear feet for boardwalk area planned for bulkheading in Corps plan.

- Costs — The Corps plan (Appendix A of Preliminary Report) has 10, 20, 50, and 100-year hurricane protection and erosion control plans. In oral communication with Corps personnel, their 10-year plan calls for a 6,100 linear foot bulkhead with rock toe and concrete cap for the boardwalk section at a total cost of $2,598,000.00 or $425.00/linear foot. The current cost estimate is $13.00/sq. ft. for steel sheet pile bulkhead without the rock toe and concrete cap. Using this figure for the interim bulkhead, which should be a minimum of 14 feet high, results in a linear foot cost of $182.00. Assume 6,100 feet of bulkhead x $182.00 = $1,110,200.00.

- Advantages of Bulkhead Method

1. There would be very little disturbance of the existing beach uses.

2. First cost would be much lower than the costs of a number of the other possible plans.

3. Maintenance costs of the bulkhead would be low, presuming that the bulkhead was constructed of material of suitable strength and durability. Reinforced concrete piling is probably a suitable candidate for this adaptation.

4. Some of the frontage in the boardwalk area may already be protected by a bulkhead of sufficiently rugged design so that new bulkhead construction along these frontage sections would not be required.

5. The present shore processes in the area would not be distrubed, thus the action would not have an adverse effect on Assateague Island.

- <u>Disadvantages of Bulkhead Method</u>

  1. The bulkhead alone would not prevent further degradation of the beach in front of Ocean City.

  2. If steel sheet piling were selected for the bulkhead construction material, coatings would have to be applied and aggressively maintained on any exposed portion of the steel.

  3. The plan does not fit well into the probable Corps of Engineers plan except for the boardwalk area.

F. <u>Partial Bulkhead Plan</u>

(Reference: Page 62 of Preliminary Report.)

- <u>Quantity</u> — Quantities to be determined as needed for the protection of individual sections.

- <u>Costs</u> — Same as for bulkhead method.

- <u>Advantages of Partial Bulkhead Method</u> — Same as for the bulkhead method, plus the following:

  1. Only those sections of the bulkhead most needed would be constructed before the Corps of Engineers plan was undertaken.

- Disadvantages of Partial Bulkhead Method — Same as for the bulkhead method, plus the following:

  1. A degree of alertness on the part of the public officials would be needed in order to detect promptly any new beach frontage which needed bulkheading.

  2. A flexible budget would be required to ensure that new bulkheading needs would be promptly funded.

G. Seawalls

More massive structures than bulkheads and placed lower on the beach face.

- Quantity — To be determined as required for maximum protection of property.

- Costs — Dependent upon size and type of material used in construction but ranging from $2,000 to $10,000 per front foot.

H. Revetments

Blanket of various types of material laid on the beach and covered with sand on the lower part of the section. *(Reference: Page 64 of the Preliminary Report.)*

- Type — A revetment (European technique) consisting of rock and asphalt mastic (a mixture of sand, mineral fiber, and asphalt) was installed in Michigan. Report on this project states that the revetment performed well in the one year since its construction. No other data available.

- Cost — The revetment installed in Michigan cost $71.00 per linear foot on a 24-foot width of beach. Due to the negative visual aspects of a revetment structure on the Ocean City beach, further cost analyses were not made for total or partial coverage of the beach front. See disadvantages listed below.

- Advantages of Revetment Method

  1. The normal shore processes are not disturbed to any great extent by the presence of the revetment.

  2. The initial cost of construction would be significantly less than some other methods of shore protection.

  3. The loss of sand from the upper beach face is greatly reduced by the revetment; the need for periodic replenishemnt of sand to the upper beach face would be greatly lessened.

- Disadvantages of Revetment Method

  1. The revetment is vulnerable to rapid spreading of damage and failure unless frequent containment walls are provided.

  2. The surface of the revetment is not adapted to ordinary beach uses unless provisions are made to cover the revetment with sand.

  3. The revetments do not protect the backshore from damage during major storms.

I. Intermittent Revetments

Same as preceding plan. *(Reference: Page 67 of Preliminary Report.)*

- Advantages of Intermittent Revetment Method — Essentially the same as the full revetment method, plus the following:

  1. Only those sections of revetment most needed would be constructed before the Corps of Engineers plan was undertaken.

- Disadvantages of Intermittent Revetment Method — Essentially the same as for the full revetment method, plus the following:

1. A degree of alertness on the part of the public officials would be needed in order to detect promptly any new beach frontage which needed revetting.

2. A flexible budget would be required to ensure that the need for new revetments would be promptly funded.

3. Adequate wingwalls would be needed at the ends of the segments of revetment to ensure that the material is not lost from behind the segments when under storm wave attack.

J. <u>Segmented Off-Shore Breakwaters</u>

Structure off-shore to break the wave energy. *(Reference: Page 69 of Preliminary Report.)*

- <u>Quantity</u> - See page 69 of Trident's Preliminary Report for possible locations.

- <u>Type</u> - There are numerous types of breakwaters ranging from simple wire-covered stone mounds to massive steel reinforced concrete structures.

- <u>Costs</u> — May range from a low at $250.00 per linear foot to over a thousand dollars per linear foot dependent upon material used in construction, size of structure, and depth of water in which placed.

- <u>Advantages of Segmented Off-Shore Breakwater Method</u>

  1. The erosion attack of the waves on the shore would be greatly reduced.

  2. There would be comparatively little sand lost from the nearshore and beach area even during storms of considerable magnitude.

  3. Surf conditions would be reduced, but not eliminated, on the Ocean City beaches; thus surf bathing could be enjoyed more days per year than at present.

  4. Yearly maintenance costs would be low if the breakwaters were properly designed and constructed.

- <u>Disadvantages of Segmented Off-Shore Breakwater Method</u>

  1. There would be very little sand moving south past the present north jetty which could ultimately reach the eroding shores of Assateague Island. The blocking of the sand would have a beneficial effect on the inlet navigation channel.

  2. The first costs would be rather large.

  3. The structure would benefit the probable Corps of Engineers plan but would not be an essential part of this Corps plan.

K. Novel Breakwater Units

Same purpose as outlined in preceding segmented off-shore breakwater method. *(Reference: Page 73 of Preliminary Report.)*

- Types — Several types investigated were:

  - ° A breakwater which consists of automobile tires bolted together and either left to float in waves or are anchored to the bottom;

  - ° A breakwater which consists of a series of steel slats mounted on a triangular-shaped steel "A" frame base;

  - ° A breakwater composed of Z-shaped concrete units bolted together to form different lengths of breakwaters.

  Based on previous tests, none of the above appear to be suitable for the Ocean City beach protection plans. One unit that has been successfully tried in other areas of shallow water is the Longard Tube. This consists of a plastic tube four to six feet in diameter filled with sand. It may be worthwhile to try on an experimental basis at Ocean City.

- Costs — Prices range from $25.00 to $90.00 (1975 prices) per linear foot, dependent upon source of sand to fill the plastic tube and other installation factors. Mobilization costs are extra.

No advantages or disadvantages are listed as this system has not yet been proven to be able to determine its usefulness at Ocean City.

L. <u>Sand Back-Passing</u>

Trapping sand at the down-drift end of littoral drift, such as at the north jetty of Ocean City, and then pumping or hauling the sand back to replenish the beach area. This method could be used to maintain the beach once the proper beach cross-section is established such as outlined for paragraph A., "Sand Replenishment". *(Reference: See page 74 of Preliminary Report.)*

- <u>Type</u> — Use of the present north jetty to trap and impound littoral drift sand. Hydraulic dredging to pump sand back to northern eight miles of beach.

- <u>Quantity</u> — 150,000 yd^3 pumped onto beaches from impoundment.

- <u>Cost</u> — Dredging costs have previously been estimated at $4.00/$yd^3$ based on a reasonable distance of pumping or hauling the sand to the beach areas. Distributing the dredged sand over an eight-mile section of beach would possibly increase the $4.00/$yd^3$ cost when it is obtained from one central location instead of from off-shore sites closer to the beach areas.

Dredging.............................	$600,000.00
15% additional for extra costs.......	90,000.00
Estimated Total Cost.................	$690,000.00

- Advantages of Sand Back-Passing Method

1. It would possibly maintain the beaches in their present position unless a major storm stuck the area.

2. It would not interfere with present uses of the beaches.

3. Maintenance of the inlet navigation channel would be made easier.

- Disadvantages of Sand Back-Passing Method

1. It would not significantly improve the present condition of the beaches.

2. The sand transportation costs from the inlet to the northerly few miles of beaches might be rather high due to the distance involved.

3. The sand would permanently be denied to Assateague Island.

M. Bulldozing

Pushing sand from lower section of beach at low tide level onto upper portion of beach. *(Reference: Page 77 and pages 33-34 of Preliminary Report.)*

- <u>Costs</u> — According to Ocean City officials, bulldozing costs were $465,315.00 for the winter period 1977-1978. The quantity of sand bulldozed was not known.

- <u>Advantages of Bulldozing Method</u>

  1. Gains protection of beach for a short period of time against a forthcoming storm. If storm is of short duration, beach will be maintained until next storm of a longer duration.

- <u>Disadvantages of Bulldozing Method</u>

  1. A temporary measure lasting only between storms that have sufficient intensity to last through two high tide cycles.

Section III
pages 1-56

FINAL REPORT

INTERIM BEACH MAINTENANCE AT OCEAN CITY

Prepared for

ENERGY AND COASTAL ZONE ADMINISTRATION
DEPARTMENT OF NATURAL RESOURCES
STATE OF MARYLAND
Tawes State Office Building
Annapolis, Maryland 21401

Prepared by

TRIDENT ENGINEERING ASSOCIATES, INC.
48 Maryland Avenue
Annapolis, Maryland 21401

Project Manager: Richard H. Wagner

Principal Investigator: Joseph M. Caldwell

CONTRACT NO. C15-79-440

August 30, 1979

INTERIM BEACH MAINTENANCE
AT OCEAN CITY

FINAL REPORT

Contract No. C15-79-440

August 30, 1979

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1.0 INTRODUCTION

This report has been prepared by Trident Engineering Associates of Annapolis, Maryland, for the Energy and Coastal Zone Administration of the Department of Natural Resources (DNR), State of Maryland, contract no. C15-79-440. This is the final report for this project. A preliminary report was prepared on July 19, 1979 for presentation to the Coastal Resources Advisory Committee (CRAC) and DNR. A summary sheet consisting of estimated costs for alternative methods of beach restoration and maintenance was prepared on July 25, 1979 for presentation to the CRAC group and DNR representatives at a meeting held on July 30, 1979 at Convention Hall, Ocean City, Maryland.

Trident Engineering presented the findings of the preliminary report and the summary sheet to the CRAC group and DNR representatives at the Ocean City meeting. They selected three alternative measures to be studied in greater detail; the details of these are contained in this report.

2.0 PURPOSE AND SCOPE OF STUDY

Trident Engineering was contracted by the State of Maryland, Department of Natural Resources, to perform a study to evaluate existing information and techniques relating to shore erosion control and beach maintenance. The purpose of the study is to assist the State in developing an approach for beach maintenance at Ocean City that could be implemented on an interim basis prior to the establishment of the U. S. Army Corps of Engineers project. The Baltimore District, U. S. Army Corps of Engineers project, "Plans of Improvement for Beach Erosion and Hurricane Protection from Ocean City Inlet to Maryland-Delaware Line", is not anticipated to be implemented for five to ten years from this date.

As stated in the contract for this project, this is a study "...to evaluate existing information and techniques for shore erosion control and beach maintenance which are applicable to Ocean City...". The scope of this contract did not permit field measurements to check the accuracy of available data. Consequently, when performing the analyses and developing the plans described in this report, the assumption has been made that the available data was sufficiently accurate for use in the analyses. This is considered a reasonable assumption. This data consists mainly of shoreline and off-shore depth changes as computed from beach profiles performed by the U. S. Coast and Geodetic Survey and the U. S. Army Corps of Engineers for the years 1850, 1929, 1947, 1965, and 1979. Other data and the estimated costs contained within this study are referenced to their sources.

3.0 SELECTED ALTERNATIVE METHODS FOR BEACH RESTORATION

The three alternative methods for interim beach restoration at Ocean City evaluated by this report are:

- Short groins (groins between ±250 to 350 feet in length);
- Long groins (groins between ±400 to 500 feet in length);
- Beach fill, or sand replenishment.

3.1 HYDROGRAPHIC DETAILS

To determine the proper length and profile for the recommended groins, it is necessary to define the water depths and beach and bottom profiles from the dune line out to about the -8 foot or -10 foot mean low water (MLW) depth. Average profiles from the dune line out to the -10 foot depth were established from the 1965 and 1979 surveys made by the Baltimore District of the U. S. Army Corps of Engineers.

In all, four average profiles were established for the northerly eight miles of shorefront, consisting of two average profiles for each of miles 2-5, and for miles 6-9 (see Figure 1).

COMPARATIVE PROFILE PLOTS
MILES 2-5 VS MILES 6-9 (FOR 1965 & 1979)

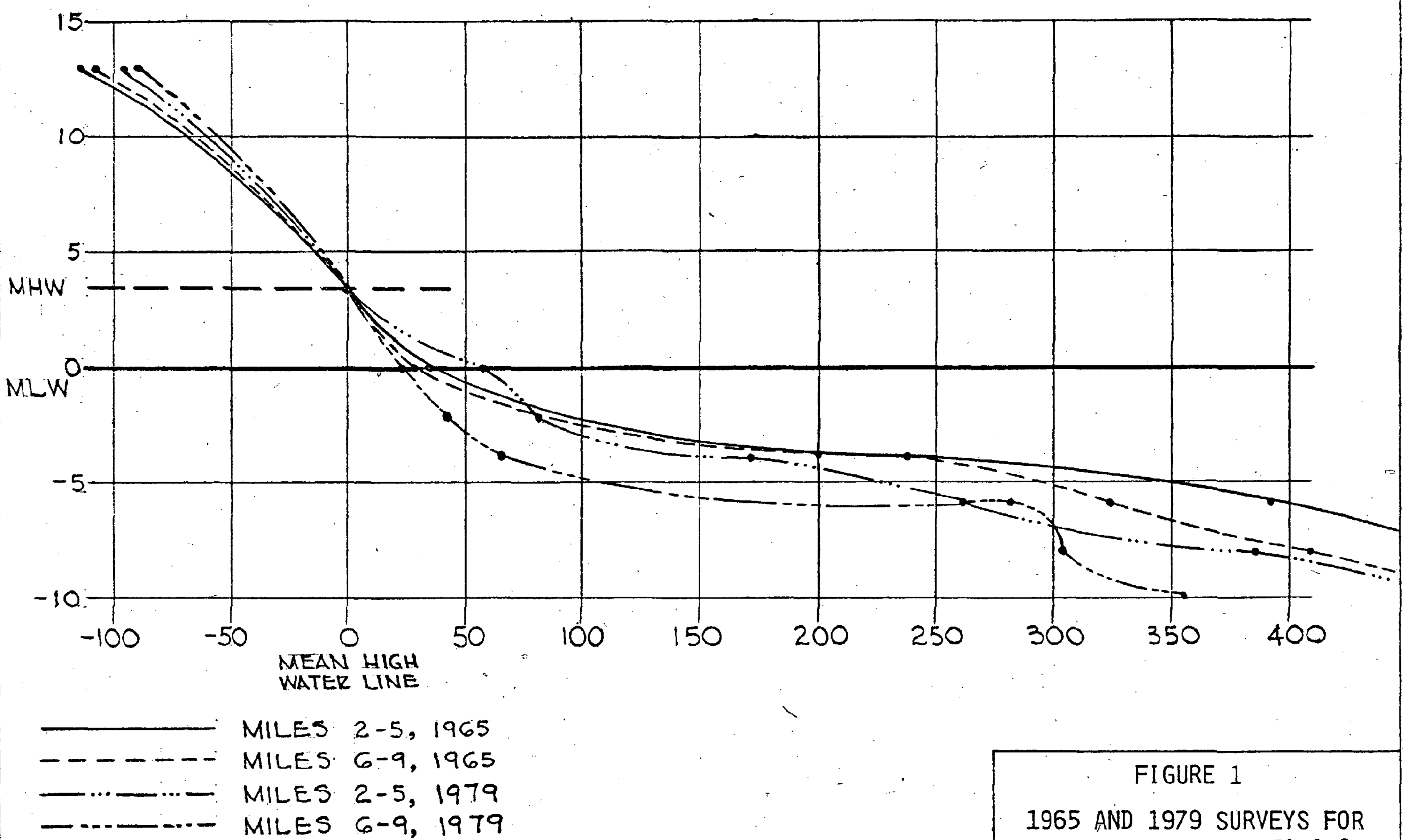


FIGURE 1

1965 AND 1979 SURVEYS FOR MILES 2-5 AND MILES 6-9

The two average profiles established for each mileage section consist of one profile from the 1965 and one profile from the 1979 Corps of Engineers surveys. To obtain each average profile, the mean high water (MHW) position on each profile was assumed as zero point, and all profile points were referred to as being so many feet seaward, or shoreward, of the zero point. To compare the profile shapes, all four average profiles were then plotted with the MHW point as a common starting point. In actuality, the 1965 MHW point is 32 feet seaward of the 1979 MHW point, as the average erosion of the MHW contour has been 32 feet over the 14-year interval, 1965-1979.

On each profile, distances from the zero point MHW were determined to the "crest of dune", to the MLW point, and to the -4, -6, -8, and -10 foot MLW points. In cases where a swale or sand bar was located offshore causing a selected depth point (say -4 feet) to appear more than once on the profile, the most seaward point was used in deriving the average. The "crest of dune" measurement required some judgement in selection and, generally, the most seaward prominent break in the profile was used, which was not alwasys the highest point shown on the profile.

The locations of the -4 and -6 foot depths are of the most interest since these are the depths planned for the short and long groins respectively. The distance from the MHW point to where the profiles crosses the -4 and -6 foot depth are outlined below:

1965 SURVEY

Distance from MHW Point	Miles 2-5	Miles 6-9	Miles 2-9 Average
To -4 foot depth	200 feet	238 feet	219 feet
To -6 foot depth	392 feet	324 feet	358 feet

1979 SURVEY

Distance from MHW Point	Miles 2-5	Miles 6-9	Miles 2-9 Average
To -4 foot depth	172 feet	65 feet	119 feet
To -6 foot depth	262 feet	282 feet	272 feet

Recapitulating the average figures for the eight miles, 2-9, we find:

Distance from MHW Point	1965	1979
To -4 foot depth	219 feet	119 feet
To -6 foot depth	358 feet	272 feet

These figures show the migration shoreward of the offshore contours in the 1965-1979 interval, as reported in Trident's Preliminary Report dated July 19, 1979. In this migration, the

-4 foot contour has move shoreward an average of 100 feet, and the -6 foot contour an average of 86 feet when referenced to the relative location of the MHW line. However, it should be noted that the actual average movement shoreward over the fourteen years, 1965 to 1979, was an additional 32 feet, as the MHW line has retreated shoreward an average of 32 feet between 1965 and 1979.

3.2 LENGTH OF GROINS

In view of the changes between 1965 and 1979, a decision was needed as to which set of depth points, 1965 to 1979, is to govern the selection of the length of the groins. The use of the 1979 distance of 119 feet for the short groin (to -4 foot depth) would result in a groin possibly too short to effectively retain the sand between the groins. The -6 foot depth distance (272 fet) in 1979 is only 53 feet seaward of the -4 foot depth distance (219 feet) in 1965. Thus, a design based on a groin extending 215 feet from the MHW point could be considered as a "short" groin based on the 1965 survey and a "long" groin based on the 1979 survey. In view of the above analysis, the following is recommended to be adopted as the distance from the MHW point to the seaward end of the groins:

MHW to Seaward End	
For short groins	— 215 feet
For long groins	— 350 feet

The 350 feet for the long groins is the average 1965 distance from the 1965 MHW line to the -6 foot MLW depth in that year.

3.3 BERM HEIGHT

The determination of the berm height is important as it controls the elevation of the inshore horizontal section of the groin. The berm is normally placed at the elevation of the upper limit of wave run-up accompanying moderate storms, not severe storms. A study of the profiles of 1965 and 1979, particularly those in Mile 1 north of the jetty which have not been disturbed by bulldozing, indicates that the natural berm elevation is about +10 feet MLW. Many of the profiles show some elevations above +10 feet; however, to set the groin elevations (up to 15 or 16 feet) would not be advisable as the groin crest would then, in many cases, form an obstruction to persons walking along the upper part of the beach. Also, these higher elevations seem — in many cases — to be dunes created by wind action rather than the true berm created by wave action. In view of the conditions as described above, +10 feet MLW will be used as the berm elevation and the shoreward horizontal section of the berm is recommended to be set at that elevation.

3.3.1 Slope from MHW to Beach Berm and "Working" Length

From MHW up to the seaward edge of the berm, the groin is usually constructed on a slope to conform to the natural beach slope. An anlysis of the position of the seaward edge of the berm in the northerly eight miles of the shore indicates that the average slope of this section of the beach (MHW to crest of berm) is very close to 1 on 10. Adopting this as the design slope and recognizing the difference in elevation between the MHW line (+3.5 feet MLW) and the berm at +10 feet MLW (a difference of 6.5 feet), the sloping section of the groin would end at a point 65 feet shoreward of the MHW point on the profile.

The "working" length of the groin is considered to be its length from this seaward edge of the berm to its seaward end. For the recommended groin lengths previously discussed with the additional length to conform to the sloping contour "working" lengths, the groins are recommended to be:

Working Length of Groins	
Short groins —	215 + 65 = 280 feet
Long groins —	350 + 65 = 415 feet

3.4 GROIN SPACING

The "Shore Protection Manual" (See Appendix B of Preliminary Report) recommends that the spacing of the groins be two to three times the working length of the groin. Using the higher figure, the groin spacing (and number required for eight miles of frontage) would be:

- Short groins — 280 x 3 = 840 feet (50 groins);
- Long groins — 415 x 3 = 1245 feet (34 groins).

It should be recognized that the 28 existing groins in the northerly eight miles can probably be modified by extending them in length and be used as part of the number of groins needed under either of these two plans.

3.4.1 Length of Shoreward Horizontal Section

The beach between two adjacent groins can be expected to orient itself to a position parallel to the wave crests arriving at the beach. This will cause the beach to be wider against one groin than it is at the other . At Ocean City, the wave action can be expected to produce a "wide" beach at the southerly end of a groin pocket, and a "thin" beach at the northerly end. The design of the groins, then, must ensure that the wide beach is contained at the southerly end and that the thin beach at the northerly end still has sufficient width to provide some degree of storm protection. *(Note: A series of storms out of the south would probably reverse the alignment in beach orientation between the groins, but the design which follows automatically provides for this condition.)*

The critical factors in determining the "offset" in the beach between the north and south end of a groin pocket is the distance between the groins and the stable angle of beach alignment. This angle is very difficult to compute with assurance but can readily be measured if a local sand impoundment condition exists. Such a condition exists north of the North Jetty at Ocean City. Measurement of the filled impoundment north of the jetty indicates an angle of about 6° as the stable angle. For the recommended groin spacings, the "offset" width of the beach between two groins would (with $\tan 6° = 0.105$) be:

- Short groins — $\tan 6° \times 840 \cong 90$ feet;
- Long groins — $\tan 6° \times 1245 \cong 130$ feet.

These two figures show the magnitude of the beach "offset" alignment within the pocket between two adjacent groins. If we assume that the thin side of the pocket should not be seaward of the existing position of the beach face, then enough beach fill must be placed inside the pocket to provide the "offset" indicated.

Additionally, the horizontal berm section of the groin must extend seaward a sufficient distance to contain this offset. Thus, the +10 feet horizontal shore section of the groin must extend seaward at the +10 feet elevation by 90 feet (for the short groin) and 130 feet (for the long groins) from the existing position of the crest of the berm. Also, this section of the groins should extend shoreward from the crest of the berm a sufficient distance to prevent flanking of the groin during a storm event. The shoreward extension from the crest of the berm should be at least 50 feet unless the shoreward end is protected by a bulkhead.

3.5 GROIN PROFILE: SHORT GROIN

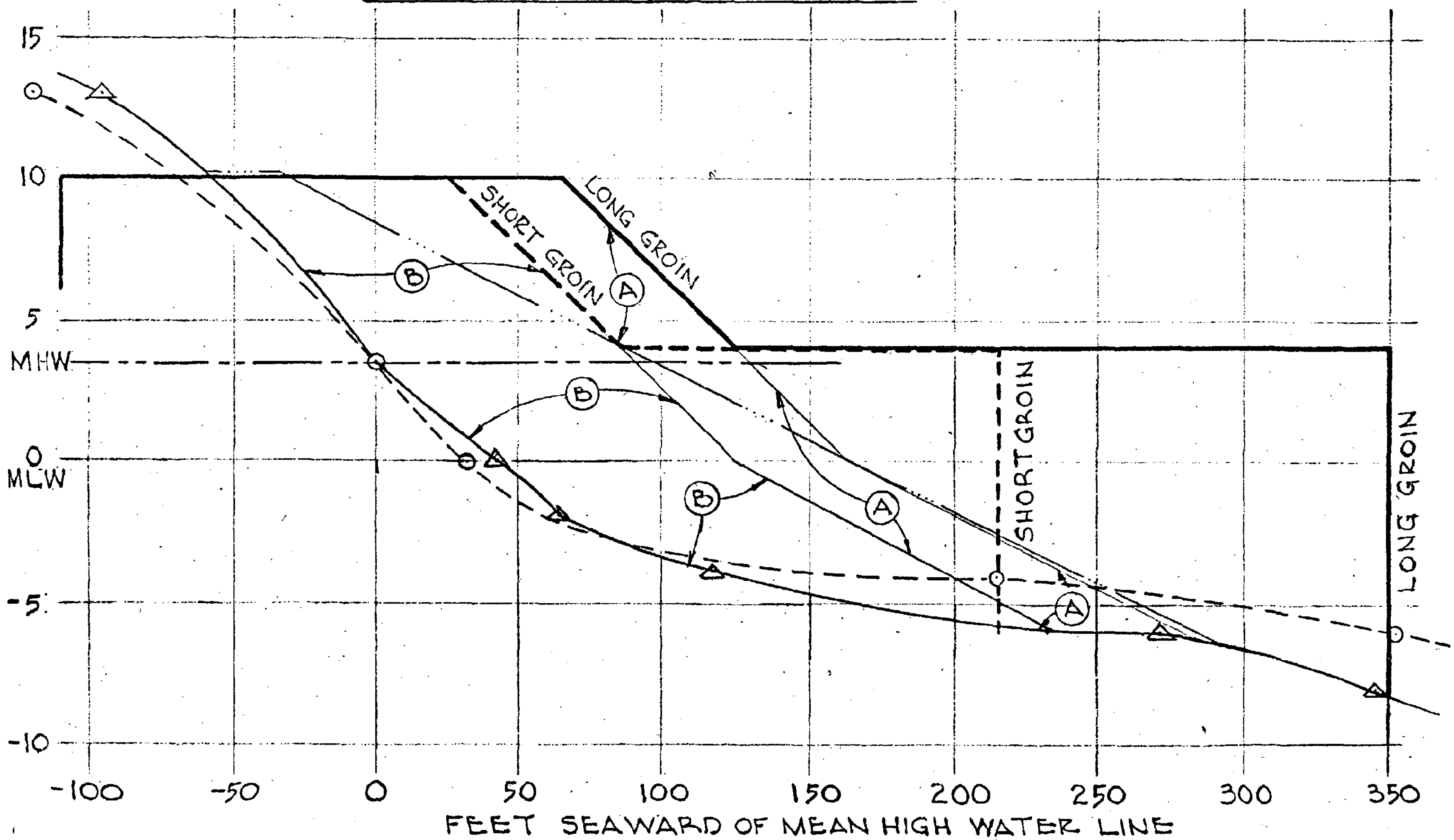
With the information previously developed, it is now possible to construct the groin profile. The only feature remaining to be selected is the elevation of the crown elevation of the seaward horizontal section of the groin. The "Shore Protection Manual" indicates the seaward horizontal section of low groins, which are the type being considered for Ocean City, should have an elevation that will permit overtopping by storm waves or by waves at high tide. Thus, the elevation of the groins should be at or near the elevation of MHW, which is +3.5 feet MLW. In order to be sure that swimmers, boaters, or surfers can see the groins under most tidal conditions, it would seem reasonable to place the crown of this outer section at about +4.0 feet MLW, which is one-half foot above MHW. The use of this higher elevation (+4.0 instead of say +2.5 feet MLW) will also make construction easier.

The short groin profile based on the above calculations is shown in Figure 2. The overall length of the groin (allowing a 50-foot penetration inshore from the crest of the berm) would be 330 feet. The 90-foot seaward extension of the +10 foot horizontal section may appear unnecessary; however, it is very much needed if the thin section of the trapped beach is to be maintained at least at its present location.

3.6 GROIN PROFILE: LONG GROIN

The profile of the long groin is almost identical with the profile of the short groin (Figure 2) except that the long groin extends seaward an additional 135 feet. Thus, the overall length of the long groin is 465 feet compared to 330 feet for the short groin. Also, the long groin requires a further extension seaward of the +10 horizontal shore section, 130 feet as contrasted to 90 feet for the short groin. This additional 40-foot extension of the berm section is due to the wider spacing of the long groins, but does not change the seaward position of the long groin.

DESIGN OF GROINS AND BEACH FILL
OCEAN CITY, MARYLAND



MILES 2 THRU 9
---⊙- AVERAGE PROFILE, 1965
—△- AVERAGE PROFILE, 1979
—···— BEACH FILL ONLY
X-SECTION OF BEACH FILL (FILLED SIDE), SHORT GROIN = SUM OF (B) AREAS.
X-SECTION OF BEACH FILL (FILLED SIDE), LONG GROIN = SUM OF (B) AREAS AND (A) AREAS

FIGURE 2
PROFILES - LONG AND SHORT GROINS AND BEACH FILL

Overall Groin Lengths

	Length* of Horizontal Berm Section at +10 ft. MLW	Length of Sloping Section	Length of Horizontal Seaward Section at +4 ft. MLW	Total Groin Length
Short Groins	140 ft.	65 ft.	125 ft.	330 ft.
Long Groins	180 ft.	65 ft.	220 ft.	465 ft.

**This length includes the 50-foot shoreward extention to prevent flanking of groins.*

3.7 FILLING THE GROINS

Filling the groins is the process, natural or man-made, by which the areas between adjacent groins are filled with sand to establish the designed beach condtions in each beach pocket between adjacent groins. As previously discussed, the beach pockets between adjacent groins will tend to align themselves at about a 6° angle with the present shoreline. If no new sand is placed in the pocket, the beach will tend to rotate horizontally about a point midway between adjacent groins. This rotation will result in the "thin" end of the pocket (probably the north end) eroding back into the shore in such a way that the crest of the berm will retreat landward about one-half of the "offset" distance. The distance of erosion is calculated to be about 45 feet for the short groins and 65 feet for the long groins.

This amount of erosion would probably cause some damage to the backshore, even under nonstorm conditions, and would probably permit severe damage under storm conditions. This type of damage can be avoided by:

- Building the groins successively, starting at the south end of the beach and not building the second groin until the first groin had filled with sand from littoral drift, and not building the third groin until the second groin had filled, etc.;

- Artifically filling the groin pockets with the required amount of sand as soon as each adjacent groin is built.

The first method would permit an average of about three long groins to be built each year, or about eleven years to complete the installation of the 34 groins. A somewhat shorter time (probably seven or eight years) would be required for the program of 50 short groins.

Under the artifical fill method, the groins could be constructed as rapidly as practicable provided the beach pockets between the groins were filled with sand immediately following construction. Using the average beach profiles and beach fill cross-section for the 1979 contour (as shown on Figure 2), the estimated fill needed for each groin pocket is:

° Short groin - 20,120 yd^3 (total for 50 groins = 1,006,000 yd^3);

° Long groin - 45,027 yd^3 (total for 34 groins - 1,531,000 yd^3).

(Note: Figure 2 shows the cross-section of sand fill for the short and long groins that would be contained on the filled side of the offset. The average amount of sand contained within each groin pocket would be less than depicted in the drawing.)

3.8 GROIN CONSTRUCTION

Groins are usually constructed of wood sheet piling, steel piling, concrete piling, or quarry stone. There are certain parameters of limitation for each type material as described below.

- Wood Sheet Piling

  Generally a satisfactory material if the piling has been treated properly against marine borers and is properly designed to withstand the differential pressures due to the sand line standing higher on one side than the other side, and also to withstand the differential wave pressures caused by waves approaching at an angle.

- Steel Sheet Piling

  Has a considerable strength advantage over wood piling, but has a severe rusting problem in salt water areas (except in cold water). Coatings to prevent rusting are needed in temperate and tropic waters, and the maintenance of these coatings is very difficult at the sand line in the surf zone.

- Concrete Piling

Concrete piling (which always requires reinforcement) suffers from fatigue cracks caused by the constant bending back and forth of the piling under wave attack. Unless very massive pilings are used, these fatigue cracks will develop sufficiently to permit the salt water to penetrate and rust out the reinforcing steel. This failure mode can be prevented by properly prestressing the piles.

- Quarry Stone

This is a suitable construction material but possibly has a higher initial cost than the other material, although if properly designed, will have a low maintenance cost. Three features of design are necessary:

1. The armor stone and underlayer stone must be of proper mass and shape to desist displacement under severe storm waves;

2. An impermeable core must be provided to prevent the movement of sand through the groins; and

3. A bedding layer, or filter layer, must be placed under the structure to prevent the core material and quarry stone armor from sinking into the bottom.

3.8.1 Groin Construction Features

The construction features of typical groins are shown on Figures 3 through 6. These plates are copied from the "Shore Protection Manual" of the Corps of Engineers.

- Figure 3 shows a timber pile groin at Wallops Island, Virginia, which is similar in construction design to the groins recently constructed at Ocean City. The size and penetration of both the sheet piling and the supporting round piles would have to be designed against local conditions, considering both the differential sand loads and differential wave loads.

- Figure 4 shows a cantilever steel sheet pile groin. Note that stone is used to help support the piling and that this piling is in the fresh waters of Lake Michigan.

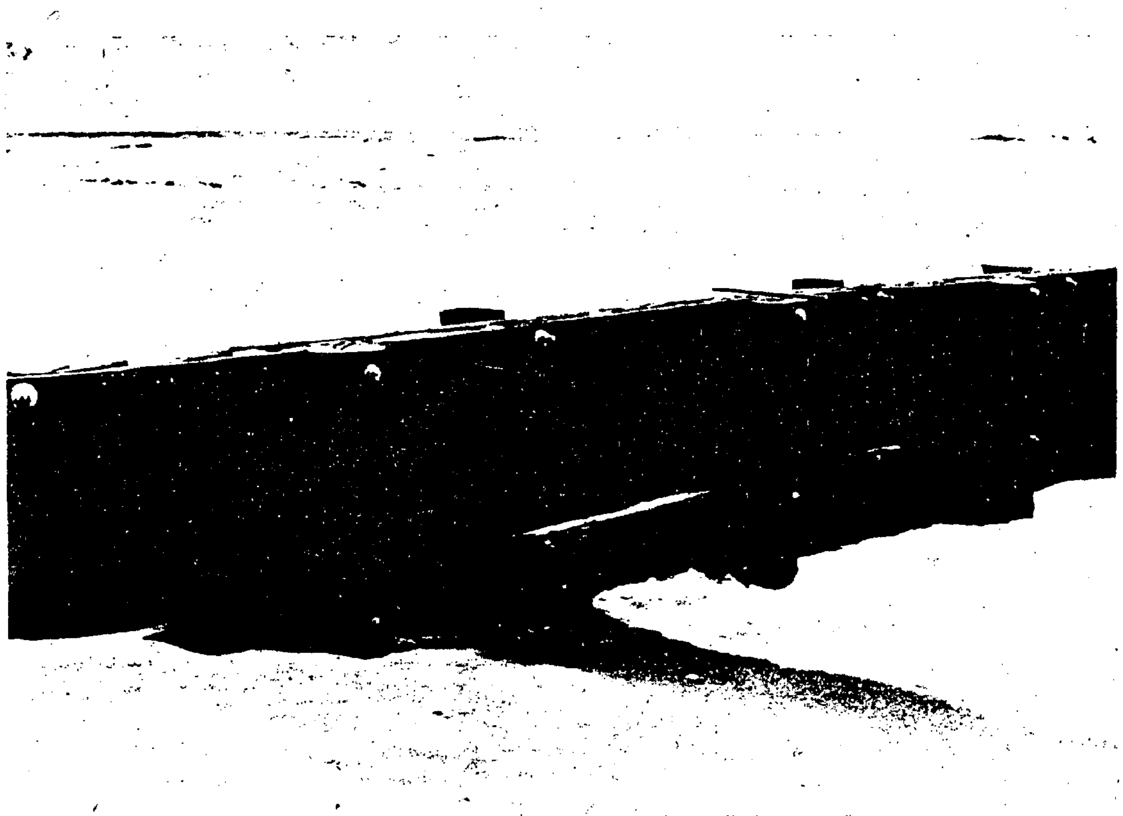
- Figure 5 shows a prestressed concrete sheet pile groin alongside a pier in the Los Angeles area.

- Figure 6 shows a quarry stone (rubble-mound) groin on Long Island. This particular groin does not have the profile recommended for Ocean City but does have the same construction features. Assuming a storm surge elevation of 3.5 feet and a tide elevation of +3.5 feet MLW, the depth at the outer end of the long groin could be in the order of 17 feet during a severe storm. This depth would permit waves as high as 13.5 feet to break against the outer end of the groin. Assuming a 1 on 2 side slope and a stone density of 165 pounds per ft^3, this would require a armor stone with an average weight of 10 tons on the head of the groins. On the trunk of the groin, the armor stone would have to be only seven tons near the outer end and one ton near the MLW line. For the short groin, the stone on the outer end should weigh about five tons.

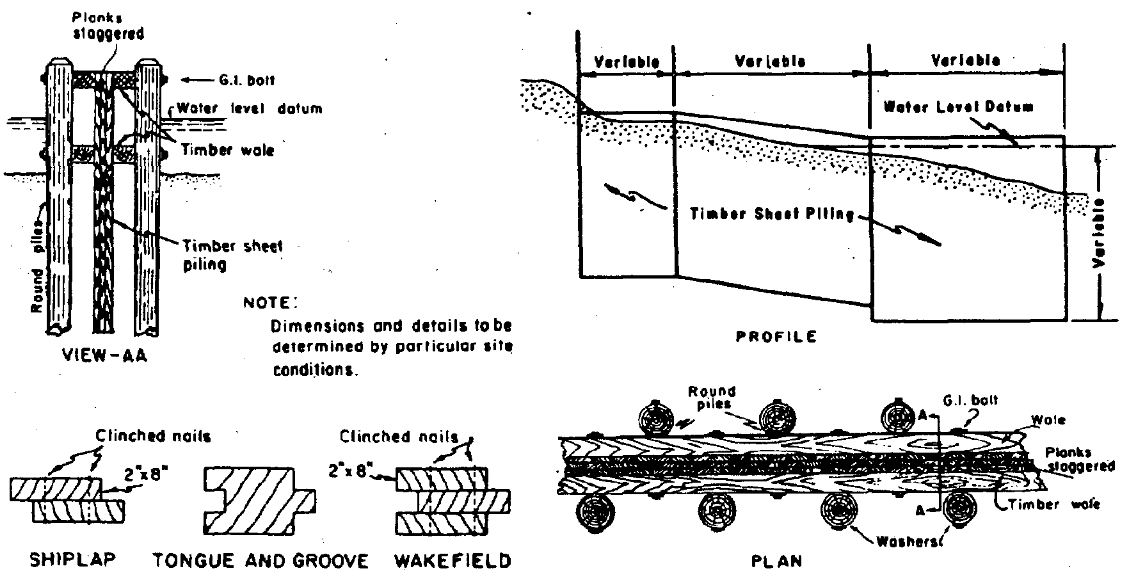
  (Note: These stone tonnages are intended for general guidance only and are not intended to be a definitive final design.)

3.9 BEACH RESTORATION

For beach restoration by the sand fill or sand replenishment method, it is assumed that an increase in berm width of 30 feet at the +10 foot MLW elevation is needed and that sand placement on a slope of 1 on 20 would be required seaward of that point



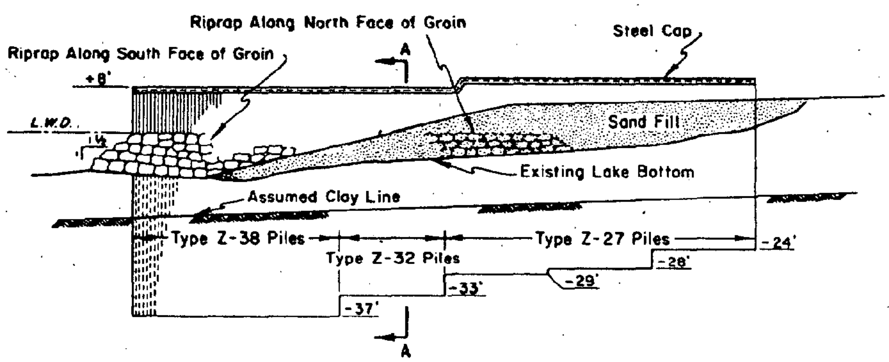
Wallops Island, Virginia (1964)

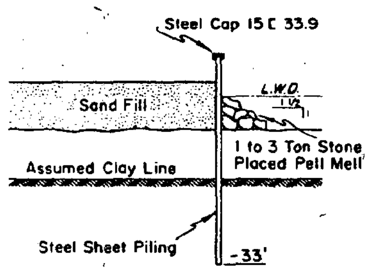


TIMBER SHEET-PILE GROIN

Figure 3

Evanston, Illinois (before 1960)



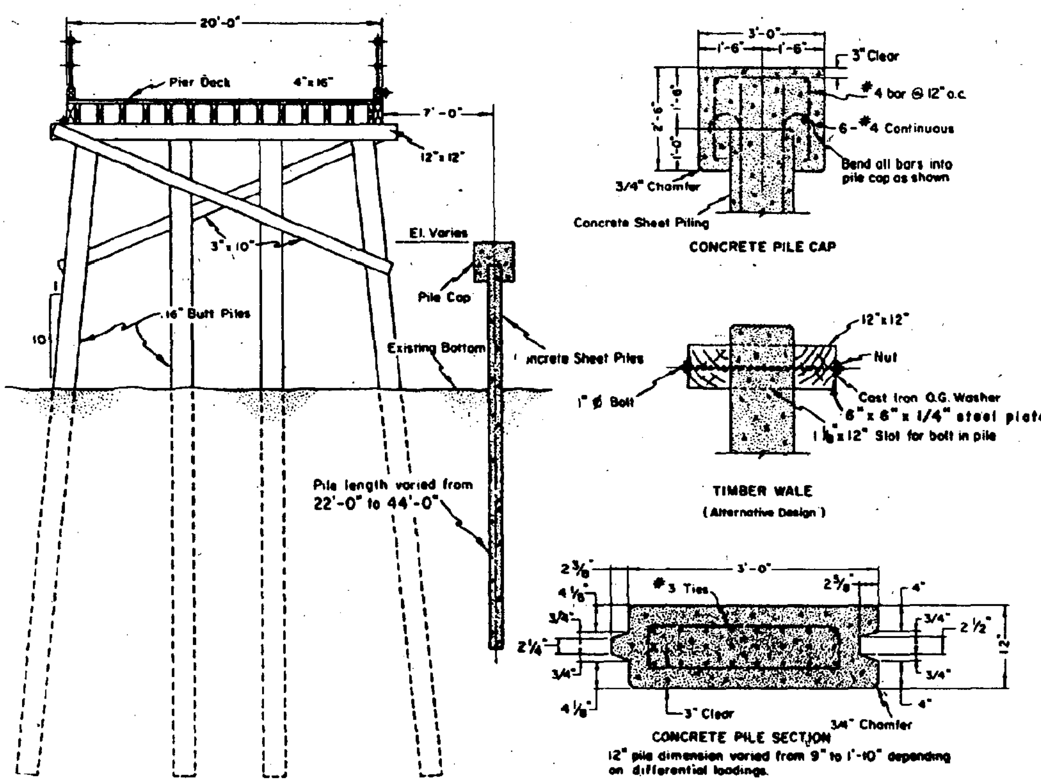


SECTION A—A

CANTILEVER STEEL SHEET-PILE GROIN

Figure 4

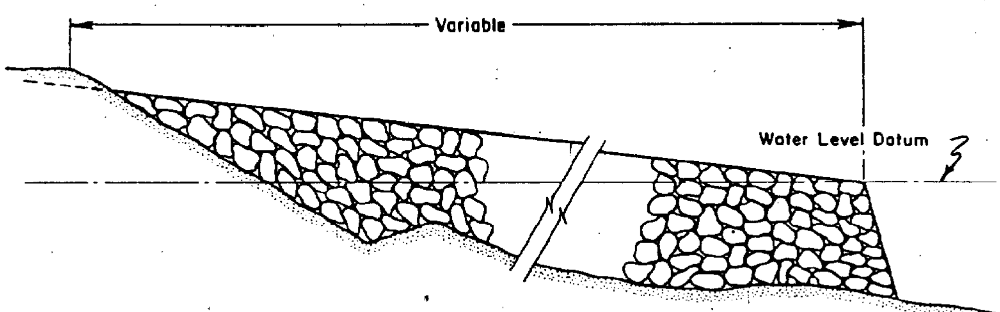
Seal Beach, California (July 1959)



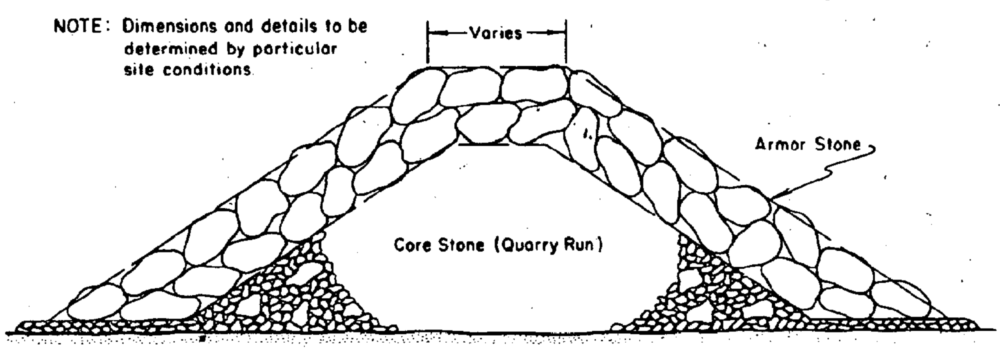
PRESTRESSED CONCRETE SHEET-PILE GROIN

Figure 5

Long Island, New York (circa 1971)



PROFILE



CROSS-SECTION

RUBBLE-MOUND GROIN

Figure 6

as is shown on Figure 2. This restoration corresponds almost exactly to the beach restoration after the 1962 storm and the fill itself could be expected to provide protection against a storm with a recurrence level of about one in ten years. No supplementary raising of the dunes behind the +10 foot MLW berm is contemplated as most areas already have elevations up to +13 feet MLW or more. This plan is in general agreement with, but not as extensive as, the plans that may be recommended by the Corps of Engineers.

The plan envisioned above would require the placement of about 61.0 yd^3 per foot of beach based on the 1979 beach profiles furnished by the Corps of Engineers. This would involve the placement of 2,577,000 yd^3 over the northerly eight miles of the Ocean City frontage.

It should be recognized that it is not possible to predict accurately the movement of this fill after placement. The considerable deepening of the waters at the -10 foot MLW depth, which has taken place over the past 50 years and appears to be continuing, might result in a significant movement of the sand fill out into deeper water. Thus, possibly a short segment of the shore, say one-half mile, should be subjected to the sand fill method before proceeding with a plan for the entire eight miles of shore.

4.0 LEVEL OF PROTECTION

4.1 GROINS

The groins themselves without sand fill between adjacent groins will not provide any appreciable degree of protection (see section 3.7, Filling the Groins). After the groins are filled, the following levels of protection are anticipated:

- Short Groins

  On the wide end of the sand fillet, an added protection of approximately an eight-year storm severity can be expected over existing conditions of the shore front at the time the groins are installed and filled. In the middle of the pocket, the added years would be about four. At the thin edge of the fillet, no additional protection would be added to the existing protection. If the fillet was parallel to the shore, the added protection would be about four years overall.

- Long Groins

  In the manner described above for short groins, the long groins would provide an additional 12 years of storm severity protection over existing conditions at the filled (wide) end of the fillet, about six additional severity years in the center, and no additional protection over and above existing conditions at the time of construction at the narrow (thin) end of the fillet. Whenever the fillet was aligned parallel to the shore, the added severity years would be about six.

4.2 BEACH FILL

The added level of protection from the beach fill or sand replenishment would protect against a storm with recurrent intervals of about ten years over the level of protection of the shore front at the time this alternative was implemented; e.g., if it can be assumed that the present shoreline is adequate to protect against a storm with a recurrence or frequency of about ten years (a 10-year storm), then the total protection with sand replenishment would provide protection against a 20-year storm. *(Note: It is not known what the present level of protection is for the Ocean City shore front. Determination of this factor requires an extensive amount of on-site survey work which is beyond the scope of this study and is not documented in existing studies.)*

5.0 COSTS OF ALTERNATIVES

5.1 INITIAL COSTS

5.1.1 Timber Groins

In the Preliminary Report summary sheet, the 1978 construction costs reported for a 201-foot timber groin built at Ocean City was $292.00 per linear foot. From rough estimate costs received from Edwin A. and John O. Crandell, Inc., West River, Maryland, a contractor who has previously constructed groins at Ocean City, a 1979 cost factor was quoted at approximately $380.00 per linear foot for a short groin, and $468.00 per linear foot for a long groin. Thus a short groin of 330 feet in overall length would cost an estimated $125,400.00, and a long groin of 465 feet overall length would cost $217,620.00. The above price estimates were based on the construction of a groin as depicted on drawing no. 3 of the "Plan and Elevation of Proposed Timber Groin at 34th Street, Town of Ocean City, Worcester County, Maryland", dated August 1976, from the files of the Shore Erosion Control Program of DNR. It should be noted that the proposed short and long groin profiles may not match that previously used for Ocean City groins which could vary the linear foot cost if the proposed groin required more or less material or different cross-section sizes.

Mr. Crandell expressed his concern about damage to the seaward end of a groin if it exceeded 250 feet in overall length. He recommended building a double wall groin approximately eight feet wide and filling the space between the groins with sand topped with stone. He recommended the double section of the groin extend from the MHW line out to the seaward end. This would double the cost for a groin for 215 feet of the short groin section, and 350 feet for a long groin (between MHW and seaward end), or a total cost for a short double groin of $207,100.00 and $381,420.00 for a long double groin.

Recap

- Short Groin - 330' long x $380.00/ft. = $125,400.00 ea.

50 Short Groins Needed for 8-Mile Section		
22 new groins @ $125,400.00 ea.	=	$ 2,758,800.00
Extension of 129' to 28 existing groins @ $49,020.00 ea.	=	1,372,560.00
		$ 4,131,360.00
Double Section Short Groins		
22 new groins @ $207,100.00 ea.	=	$ 4,556,200.00
Extension of 129' to 28 existing groins @ $98,040.00 ea.	=	2,745,120.00
		$ 7,301,320.00

- Long Groin — 465' long x $468.00/ft. = $217,620.00 ea.

<u>34 Long Groins Needed for 8-Mile Section</u>	
17 new groins @ $217,620.00 ea.	= $ 3,699,540.00
*Extension of 264' to 17 existing groins @ $123,552.00 ea.	= 2,100,384.00
	$ 5,799,924.00
<u>Double Section Long Groins</u>	
17 new groins @ $381,420.00 ea.	= $ 6,484,140.00
*Extension of 264' to 17 existing groins @ $247,104.00 ea.	= 4,200,768.00
	$10,684,908.00

**Due to the wider spacing of the long groins, it is estimated that only 17 of the 28 existing groins could be extended in length and maintain the proper spacing between groins.*

Note: The length for extension of both the short and long groins was figured from the seaward ends of the existing groins rather than from the MHW line to allow for existing conditions, assuming the present groins are properly constructed from their seaward end to the MHW line.

5.1.2 Stone Groins

The only recent stone groin construction cost estimate available within the general area of Ocean City, other than for the 80-foot stone groin extensions that the city, itself, had constructed, was done by the Philadelphia District of the Corps of Engineers. The Operations Division of the Philadelphia District quoted the following figures that they used this year (1979) for a proposed stone groin at Cape May, New Jersey:

- Material and labor cost estimate per tonnage of stone - $35.00/ton

- Tonnage required per cu. yd. of groin - 2 tons/yd³

The Philadelphia District believes that the groins at Ocean City and Cape May are close enough in overall size, tonnages, and design characteristics that the cost factors would be applicable in either location.

Using the Corps of Engineers cost estimate, the cost of short and long groins, based on the design characteristics given in sections 3.8 and 3.8.1, are:

- Short groins at 330' length with a 10' width crown and end cap - Total volume of 2232.88 yd^3 from the various sized cross sections
  2232.88 yd^3 x 2 $tons/yd^3$ x $35.00/ton = $156,302.00 ea.

The short groins would thus cost an estimated $473.64 per linear foot.

<u>50 Short Groins Needed for 8-Mile Section</u>

22 new groins @ $156,302.00 ea.	= $ 3,438,644.00
Extension of 129' to 28 existing groins @ $61,100.00 ea.	= 1,710,800.00
	$ 5,149,444.00

- Long groins at 465' length with a 10' crown and a 15' crown for the last 50' seaward end to accommodate the 10-ton stone size and end cap - Total volume of 4697.7 yd³ x 2.0 x $35.00 = $328,844.00 ea.

$\frac{\$328,844}{465'}$ -or- $707.19/linear foot

<u>34 Long Groins Needed for 8-Mile Section</u>

17 new groins @ $328,844.00 ea.	= $ 5,590,355.00
Extension of 264' to 17 existing groins @ $186,698.00	= 3,173,869.00
	$ 8,764,224.00

The Philadelphia District stated that they normally use a 2.0 ton per yd³ for planning purposes (as was used for the above calculations). However, for actual construction projects, a 1.7 factor can sometimes be used. If construction of stone groins at Ocean City is contemplated by the State, it may be found that a bidding contractor could construct the groins at a rate closer to the 1.7 than the 2.0 factor. This would reduce the cost of a short groin by $23,445.00 each, or $132,857.00 instead of $156,302 each; and a long groin from $328,844.00 to $279,513.00 or a difference of $49,331.00 each.

The actual costs bid for a job will depend upon several variables such as the total number of groins to be built by a single contractor, time and date limits imposed, methods of material haul (water, rail, or road), mobilization costs, etc. As these are unknown for this estimate, the 2.0 factor was used to compute the cost of construction on a maximum scale rather than a minimum level.

One other area where a savings may be obtained is in areas where there is a bulkhead that the groin can be tied into. The lengths of both the long and short groins include a 50-foot section for tie-in to the dune that would not be needed where a bulkhead exists.

5.1.3 Cost of Filling Groins

In section 3.7, it was stated that the groins could be filled either from littoral drift or by artifical means. If the groins are built from south to north, one at a time, and the second groin is not built until the first groin has filled, the sand can be obtained from littoral drift; but the method will require a number of years before all the groins could be installed. Using an artifical fill method, the groins can be constructed as rapidly as possible.

Assuming the groins were to be built as rapidly as possible, sand fill would be required upon completion of each groin.

Also, assuming that no more than ten groins per year could be built due to weather and summer time use of the beach restrictions, a total of 201,200 yd^3 of sand would be needed for ten short groins or 450,270 yd^3 for ten long groins. Based on previous hydraulic dredging costs and cost estimates from variable sources and quantities to be dredged as outlined below, it is estimated that it would cost approximately \$4.00/yd^3 for sand in quantities less than 1.5 million yd" at one time. At \$4.00/ yd^3, the sand fill for ten short groins would be \$804,800.00, and \$1,801,080.00 for ten long groins.

The total costs for sand fill for all groins at \$4.00/yd^3 would be:

- ° Short Groins - 50 ea. with 1,006,000 yd^3 of sand - \$4,024,000.00
- ° Long Groins - 34 ea. with 1,531,000 yd^3 of sand - \$6,124,000.00

This is assuming that the groins could not or would not be built all at one time to take advantage of a lower cu. yd. cost of hydraulic dredging. If, in fact, all groins were built in the same year, a lower unit cost of sand could probably be realized as outlined in section 5.1.4 below.

5.1.4 Beach Fill

In the Preliminary Report summary sheet for this study, the cost for hydraulic dredging was estimated at $4.00/yd³. This cost was based on the latest figure from the Baltimore District Corps of Engineers from a contract they let to dredge 60,000 yd³ from the Ocean City Inlet in 1978. It was also stated in the summary sheet that large volume dredging had in previous years been bid at lower costs, ranging from $.77 to $1.77 for quantities of 3.5 to 1.5 million yd³.

The Baltimore District has previously made cost estimates independently for the beach fill alternatives for their Ocean City study. (The information sheet for this project is contained in Appendix A of Trident's Preliminary Report.) The Baltimore District cost estimates for their beach fill alternatives, based on 1977 prices, for hydraulic dredging from offshore sources, OB 1 and OB 2 (see Figure 7), and from Land Borrow are:

Sand Source	Hydraulic Dredging Unit Cost		
	3.5 million yd³	2.5 million yd³	1.5 million yd³
OB 1	2.23	2.25	2.29
OB 2	2.93	2.96	3.23
Land Borrow within 10 miles	2.35	2.35	2.35

The 1977 cost estimates did not include the OB 3 (Figure 7) source, which is new source recently included in the Corps study.

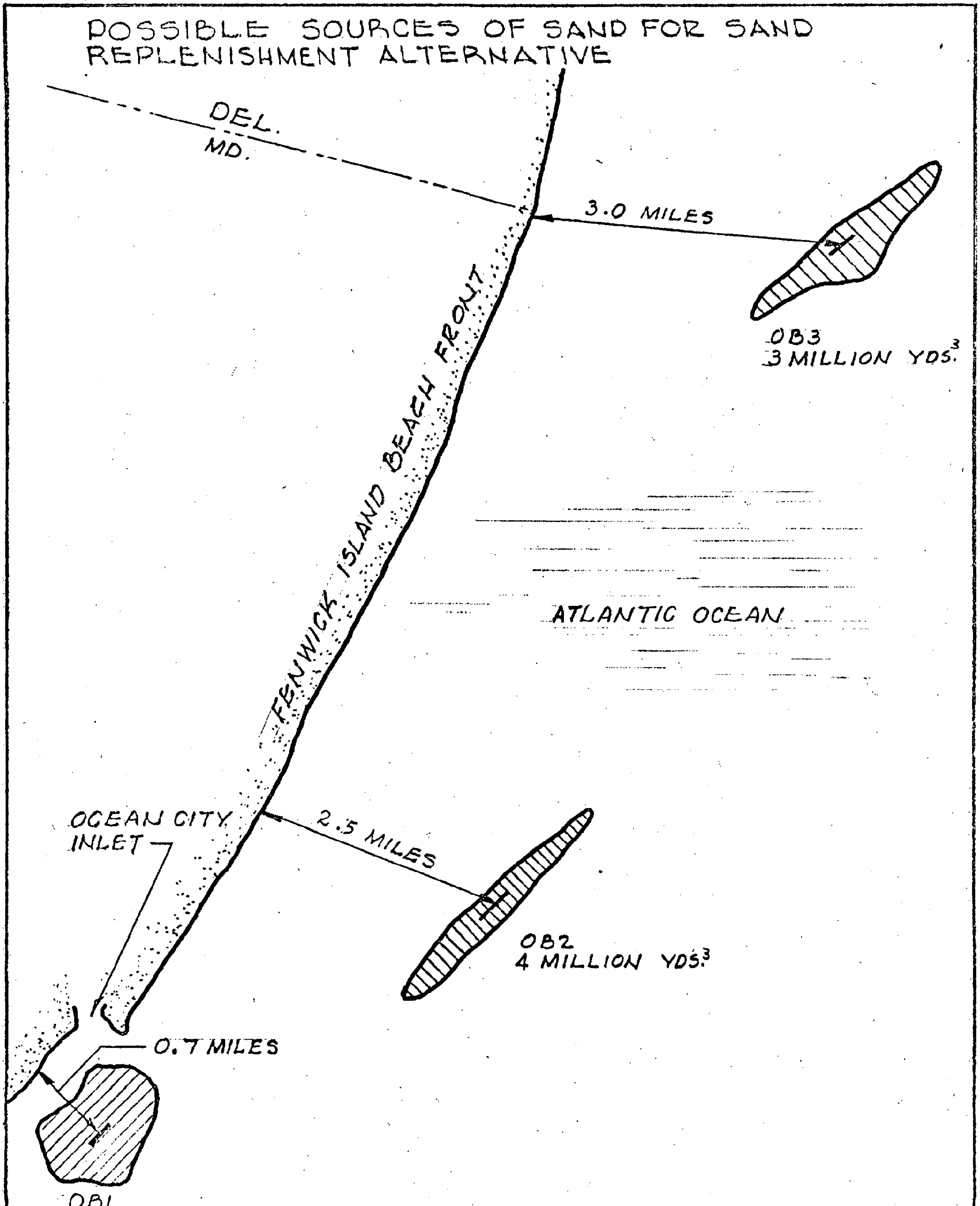


FIGURE 7

OFFSHORE LOCATIONS OF SAND DEPOSITS

It is assumed that the OB 3 source costs would be slightly higher than those listed for OB 2 due to the additional distance of 0.5 mile to pump or transport the sand.

The beach fill alternative, section 3.9, calls for placement of 2,577,000 yd^3 on the northerly eight miles of shore front. There are three possible sources of sand for this method, which are identified in Figure 7. As can be seen from this figure, any one of the three sources has adequate quantities to satisfy the beach fill method. In practicality, a contractor would probably use all three sites to pump sand to the shore front from the closest possible source to the different sections of the eight miles of beach. Assuming this, an average figure for dredging and placing the sand on the shore front for 2.5 million yd^3 might be in the range of $2.85/$yd^3$, considering the extra distance from OB 3 and that all eight miles of shore front are to receive an equal amount of sand from all sources. This figure must, of course, be escalated from the 1977 estimate to the year that the dredging is to be accomplished. Using the average figure of $2.85/$yd^3$ for planning purposes, the 2,577,000 yd^3 needed for this alternative would thus cost $7,344,450.00.

As further identified by the Baltimore District Corps of Engineers, the grain size of sand from the three sources, OB 1, OB 2, and OB 3, are comparable to the grain size of sand presently found on the Ocean City beach. The following table is an extract of data furnished by the Baltimore District Corps of Engineers.

GRAIN SIZE ANALYSIS - STATISTICAL PARAMETERS					
Composite Samples		Mean	Sorting	16%	84%
From Ocean City Beach	in phi	2.02	0.96	1.059	2.984
	approx. mm size	0.25	0.5	0.48	0.13
OB 1	in phi	1.83	1.00	0.826	2.832
	approx. mm size	0.28	0.5	0.56	0.14
OB 2	in phi	2.04	0.62	1.428	2.661
	approx. mm size	0.24	0.65	0.37	0.16
OB 3	in phi	0.94	0.82	0.118	1.757
	approx. mm size	0.52	0.56	0.92	0.29

6.0 MAINTENANCE COSTS

6.1 BEACH FILL ALTERNATIVE

It is estimated that it will require approximately 150,000 yd^3 per year to maintain the shore front to the level achieved under the beach fill alternative for protection against a 10-year storm. This quantity is considered an average annual requirement that would be needed regardless of storm frequencies or intensities.

Any large storm (+10-year intensity) will reduce the beach width and cause a loss of sand from the shore front out into deeper water. Normally, some of the sand lost to deep water from a storm will be returned to the beach during periods of calm weather. The amount of sand permanently lost to deep water from a storm would, of course, vary with the storm's intensity. The amount of replenishment needed to restore the beach to its original form would, therefore, vary, and this quantity is not contained within the estimated normal annual replenishment amount of 150,000 yd^3 per year.

As the annual replenishment quantity is not large enough to enjoy a reduced unit cost price, it is estimated at \$4.00/yd^3 for dredging and placement on the shore front.

Annual Maintenance Cost: Beach Fill

150,000 yd^3 x \$4.00 = \$600,000.00

6.2 GROINS

The use of groins will provide a wider beach which will not require as large a quantity of replenishment sand to maintain the shore front. It is estimated that after the groins are initially filled, approximately 75,000 yd^3 sand would be required on an annual basis to maintain the beach width achieved under the long or short groin method. The long groins would require a slightly less amount; but for planning purposes, 75,000 yd^3 is estimated for replenishment requirements for both systems.

Annual Maintenance Cost: Groins

75,000 yd^3 x \$4.00 = \$300,000.00

6.3 SUMMARY OF COSTS

The following initial construction costs and annual sand fill maintenance costs are listed for direct comparison. The costing methods and assumptions are as explained in the pertinent sections of the text above.

- Timber Groins

1. Short Timber Groins

50 Short Groins

22 new groins @ $125,400..................	$ 2,758,800
129' extension to 28 groins @ $49,020......	1,372,560
Sand fill for 50 short groins (page 35)....	4,024,000
Estimated initial cost, 50 short timber groins.............	$ 8,155,360
Annual cost to replenish sand (page 41)....$	300,000

Double-Section Short Groins

22 new groins @ $207,100..................	$ 4,556,200
129' extension to 28 groins @ $98,040......	2,745,120
Sand fill for 50 short groins (page 35)....	4,024,000
Estimated initial cost, 50 double-section short timber groins......	$11,325,320
Annual cost to replenish sand (page 41)....$	300,000

2. Long Timber Groins

34 Long Groins

17 new groins @ $217,620..................	$ 3,699,540
264' extension to 17 groins @ $123,552.....	2,100,384
Sand fill for 34 long groins (page 35).....	6,124,000
Estimated initial cost, 34 long groins.....	$11,923,924
Annual cost to replenish sand (page 41)....$	300,000

Double-Section Long Groins

34 long groins

17 new groins @ $381,420..................	$ 6,484,140
264' extension to 17 groins @ $247,104.....	4,200,768
Sand fill for 34 long groins (page 35).....	6,124,000
Estimated initial cost, 34 double-section long groins........	$16,808,908
Annual cost to replenish sand (page 41)....	$ 300,000

- Stone Groins

1. Short Stone Groins (from section 5.1.2 Stone Groins)

50 Short Groins

22 new groins @ $156,302..................	$ 3,438,644
129' extension to 28 groins @ $61,100......	1,710,800
Sand fill for 50 short groins (page 35)....	4,024,000
Estimated initial cost, 50 short groins....	$ 9,173,444
Annual cost to replenish sand (page 41)....	$ 300,000

2. Long Stone Groins (from section 5.1.2 Stone Groins)

34 Long Groins

17 new groins @ $328,844..................	$ 5,590,355
264' extension to 17 groins @ $186,698.....	3,173,869
Sand fill for 34 long groins (page 35).....	6,124,000
Estimated initial cost, 34 long groins.....	$14,888,224
Annual cost to replenish sand (page 41)....	$ 300,000

- <u>Beach Fill</u>

Initial Cost:

2,577,000 yd^3 @ \$2.85/yd^3.................\$7,344,450

Annual cost to replenish sand.................\$ 600,000

7.0 IMPACT ON SEDIMENT MOVEMENT

7.1 BEACH FILL

The "beach fill only" alternative would certainly not decrease the present rate of littoral drift moving south into the Ocean City Inlet complex and may even increase the rate due to the toe of the beach slope being in deeper water than at present. Thus, it is estimated that this plan might have a negative effect on the inlet navigation channel by increasing the shoaling rate. However, it would not have a more significant effect on Assateague Island than presently exists due to the inlet and jetties and could — if it increases the rate of littoral drift — ultimately have a slightly beneficial effect on Assateague Island by providing more sand which could be bypassed across the inlet to the Island.

7.2 GROINS

Both groin plans would possibly have a beneficial effect on the navigation channel as they are estimated to reduce the rate of littoral drift in the order of 75,000 yd^3 per year. At the same time, this same reduction in littoral drift rate — if it took place — could have a detrimental effect on Assateague Island by providing less sand which could be bypassed across the inlet to the Island's shore front.

It should be recognized that the use or nonuse of the three alternatives will have essentially no effect, pro or con, on Assateague Island so long as the navigation channel is maintained at a 10-foot depth or more and the dredged sand from the channel is placed somewhere other than on the north end of the seaside beach of Assateague Island. Even if, and when, placed on this north end beach, the sand so placed will lose much of its effectiveness until such time as the south jetty is raised sufficiently to prevent the sand from moving back across the south jetty into the inlet.

8.0 CORPS OF ENGINEERS PLANS

The Baltimore District Corps of Engineers "Plans of Improvement for Beach Erosion and Hurricane Protection from Ocean City Inlet to Maryland-Delaware Line" presently consist of the actions which are briefly described below, to allow an analysis of compatibility with the alternatives presented in this report. Complete details of the Corps plans are contained in Appendix A of Trident's Preliminary Report for this project.

- Storm or Hurricane Protection Plan

  - Widening and raising the beach (by sand replenishment) along the entire reach from 10th Street to the Maryland-Delaware line.

  - Creating a dune line (by sand replenishment) from the end of the boardwalk to the Maryland-Delaware line.

  - Constructing a steel sheet pile bulkhead from the end of the boardwalk to several blocks south of 10th Street.

  This plan has four levels of storm protection where "widening and raising the beach" would vary the beach width to be provided dependent upon whether it was to be built up for storm protection of a 100, 50, 20, or 10-year storm.

- Beach Erosion Control Plan

  The Corps studied four other plans which would provide for beach erosion control only, no storm or hurricane protection. These plans consisted of widening and raising the beach to four different levels. There would be no bulkheading and no construction of a dune line.

  Both plans will require periodic replacement of sand to the beach front of approximately 100,000 yd^3 per year.

In addition to the plans outlined above, the Corps is also studying a "Sand Back-Passing/By-Passing System at Ocean City Inlet". This system incorporates the use of a jetty to create a deposition basin to trap sand eroding from Ocean City's beach. The trapped sand could then be used to nourish the Ocean City beach by pumping the sand back (sand back-passing) or to nourish the northern end of Assateague Island (sand by-passing). The details for this plan are contained in Enclosure 1 to Appendix A of Trident's Preliminary Report of July 19, 1979 for this project.

9.0 RELATION OF ALTERNATIVES TO CORPS OF ENGINEERS PLANS

- Beach Fill Alternative

The "beach fill only" alternative coincides directly with the Corps plans. This is particularly true for the Corps plan for protection against a storm with an expected recurrence interval of 10 years (a 10-year storm) as this alternative and the 10-year storm Corps plan are essentially the same. The "beach fill only" alternative would also fit in with all the other Corps plans as all Corps concepts involve placing sandfill on the shore to an extent equal to or greater than the alternative of this report. Whatever sand was on the beach at the time the Corps project was being installed would act to reduce the sandfill required under the Corps plan and thereby reduce, somewhat, the local (state, county, or city) share of the overall project cost.

- Groin Plans

The statements made above relative to the "beach fill only" alternative apply equally to long groin and to short groin alternatives. In addition, both groin plans could be expected to reduce the yearly sand maintenance costs by about one-half if the Corps adopts its present 10-year storm plan. Some reduction in maintenance might be effected also for the 20-year storm plan. However, the Corps plans for 50-year and 100-year plans would probably not be affected noticeably by the groins as the inner ends of the groins would be buried by the fill being placed on the shore face.

The beach fill cross-section recommended in this study as shown in Figure 2 was derived from the plan of beach restoration designed and used by the Corps of Engineers following the great storm of March, 1962. This design was for a 10-year storm and is documented in Appendix 6-7 to the Corps of Engineers report on the 1962 storm entitled, "Operation Five-High", dated August 1963, of which this study follows almost exactly the minimum allowable section for 10-year storm protection. In view of the fact that Trident's task was to consider interim beach maintenance measures for Ocean City, the "minimum" 10-year storm section, which uses a 30-foot wide berm at +10.0 ft. MLW rather than a wider berm, of say 50 feet, was considered the most appropriate plan.

10.0 PRIORITY AREAS

The detection of the beach areas needing attention on a priority basis involves not only a study of the offshore hydrography and the location and height of the crest of the berm (or the dunes), but also a study of the relation of the shoreline buildings with reference to these other features. A comprehensive study, including the location of the buildings, the depth and type of the building foundations, and the location and type (including penetration) of any protective bulkheads, would have to be made before a reliable selection of priority shore areas could be made. Such a study is beyond the scope of the present investigation. It is possible, however, to give an indication as to where the priority areas might be located by examining the offshore hydrography and the location of the MLW line with reference to the survey base line.

One indication of possible priority need is to compare the distances on the 1979 survey profiles from the MLW line to the -4, the -6, and the -8 foot MLW points on the profiles. The closer in shore that these contours are located, the greater would be the tendency for further erosion. The following tabulation gives these distances, though it is to be noted that a number of profile points are missing at the -4 and -6 foot depth points due to being omitted on the 1979 Corps survey.

ESTIMATED PRIORITY AREAS

(DISTANCES ARE FROM MEAN LOW WATER TO MOST SEAWARD INTERCEPT OF THE STATED DEPTH POINT ON THE PROFILE.

DISTANCE MEASUREMENTS ARE FROM THE CORPS OF ENGINEERS 1979 PROFILES.)

Nearby Street	Profile Number	Base Line to MLW	Mean Low Water	-4 Foot Point	-6 Foot Point	-8 Foot Point
10th	6	540 ft.	0	40 ft.	160 ft.*	360 ft.
15th	8	415 ft.*	0	40 ft.	70 ft.*	120 ft.*
20th	9	420 ft.*	0	55 ft.	65 ft.*	315 ft.
25th	10	450 ft.*	0	60 ft.	345 ft.	365 ft.
	(Note 1)					
32nd	13	670 ft.	0	N	N	230 ft.*
41st	15	750 ft.	0	345 ft.	445 ft.	545 ft.
48th	17	690 ft.	0	N	N	N
56th	19	750 ft.	0	N	310 ft.	350 ft.
66th	21	800 ft.	0	150 ft.	250 ft.	350 ft.
76th	23	640 ft.	0	N	270 ft.	290 ft.
86th	25	580 ft.*	0	45 ft.	260 ft.	280 ft.*
PP 114	27	610 ft.*	0	N	N	270 ft.*
PP 124	29	640 ft.	0	N	N	290 ft.
Cropper	31	590 ft.*	0	N	325 ft.	370 ft.
PP 141	33	700 ft.	0	40 ft.	175 ft.*	215 ft.*
Roosevelt	35	750 ft.	0	30 ft.	N	N
Maryland-Delaware Line	37	760 ft.	0	25 ft.	N	N

Notes: (1) *The baseline shifts westward from the Boardwalk to Philadelphia Avenue between profiles 10 and 13.*

(2) *The letter "N" indicates that this part of the profile was not shown on the drawings.*

(3) *The "*" mark indicates the shortest four or five distances in each depth category. None are shown for 4-foot depth.*

Actually, so many points were missing at the -4 foot depth elevation that no assignment of priorities was attempted. At the -6 foot depth elevation, three of the four shortest distances were in Mile 2 (at profiles 6, 8, and 9) between about 10th Street and 20th Street. The fourth shortest distance was at PP 141. For the -8 foot depth contour points, the shortest distance was at 15th Street; the second at PP 141; and the third, fourth, and fifth were at 32nd, PP 114, and 86th Streets.

The significance of the above measurements is difficult to assess, and this analysis should not be interpreted to carry a recommendation that work be undertaken first at the indicated locations. A more detailed analysis, as previously indicated, would have to be made before any firm recommendations could be made as to priority locations.

11.0 CONSTRUCTION OF GROINS OR BEACH FILL AT PRIORITY AREAS

11.1 ISOLATED GROIN FIELD

The use of an isolated set of groins to reinforce a thin section of the shore at a "priority area" has a severe drawback in that the set of groins will tend to cause erosion south of the most southerly groin. Thus, if a set of groins were installed to protect, say Mile 6, then the shore front of Mile 5 would tend to erode severly unless the groins were filled when constructed. The downdrift erosive effect can be greatly curtailed by filling groins when constructed; however, even when the groins are filled, the disturbance caused by the groins to the normal travel patterns of the littoral drift might result in some erosion downdrift. There have been proposals that this downdrift erosion could be avoided by making the one or two most southerly groins of shorter length (both offshore and on the seaward end of the horizontal berm section) than the other groins. However, no design guidance is available for this proposal and this type of action would be in the nature of an experiment. (See section 3.7 for the recommended number of groins for the Ocean City shore front and sequence of construction.)

11.2 ISOLATED BEACH FILL

Beach fill can, of course, be placed where needed. However, isolated pockets of beach fill will tend to be dissipated rather rapidly by the littoral drift carrying the sand to the south. Here the temptation is to attempt to hold the isolated fill with groins, but the most southerly groin could be expected to cause erosion to the south by stopping the littoral drift. As previously stated, there have been proposals that this erosion could be avoided by making the southerly one or two groins shorter in length than the other groins. Also as stated, no design guidance is available for this proposal, and this type of action would be in the nature of an experiment. Such an experiment might be worthwhile, however, if a pressing need develops along a portion of the Ocean City frontage.

If the entire beach fill is placed over the northerly eight miles of shore as a continuous operation, then it can be presumed that each section of beach receives sand from the north and loses sand to the south in a more or less continuous operation. Thus the need for groins to prevent erosion downdrift from a beach section is eliminated. The use of groins with the beach fill would, however, tend to stabilize the beach into a uniform condition and eliminate the spot erosion which tends to develop in an irregular pattern along the shore face.

12.0 PREDICTED RESULTS

This report has developed in detail the three plans (short groins, long groins, and beach fill only) selected for further consideration and development by state officials. The designs and assessments given in this report have followed closely the standard practice as given in the "Shore Protection Manual" prepared by the Coastal Engineering Research Center of the U. S. Army Corps of Engineers. This manual is internationally accepted as being the most authoritative work dealing with shore processes and shore erosion control. The users of this report should recognize, however, that the design of shore control structures, including beach fill projects, is not an exact science comparable to the design of a bridge or an office building. The natural forces along the shore and the effectiveness of remedial works are not fully understood, and the results of installing corrective measures may not match the predicted results with a high degree of accuracy. However, the plans described in this report could be expected to have a marked beneficial effect on the Ocean City shore front in general agreement with the predicted results.

Section IV
pages 1-11

ADDITIONAL DATA FOR TRIDENT'S INTERIM BEACH MAINTENANCE AT OCEAN CITY REPORT

This "handout" has been prepared for use by members of the Coastal Resources Advisory Committee (CRAC) in their October 5, 1979 meeting to review the proposed construction of groins at Ocean City as an interim beach erosion control measure.

Trident previously studied alternative shore erosion control measures that could be implemented by the State as an interim measure prior to the time the Corps of Engineers plans will be initiated. These alternative erosion control measures are contained within our "Interim Beach Maintenance at Ocean City" Preliminary Report dated July 19, 1979. The Ocean, Bays, and Beaches Subcommittee and the Department of Natural Resources (DNR) selected three of the alternative measures -- long groins (465 feet long), short groins (330 feet long), and beach fill methods -- for further study, which are contained within our Final Report dated August 30, 1979. From the presentation of the Final Report on September 10, 1979, the selection was made by the Ocean, Bays, and Beaches Subcommittee to recommend construction of the short groins at Ocean City.

Since that period of time, the DNR has requested Trident to provide additional information consisting of:

1. Typical cross-sections of a conceptual design of the short stone groin;

2. Recommended locations and spacing of the short stone groins on the Ocean City beach, considering use of existing groins that can be extended to the recommended length of 330 feet;

3. Implementation plan or sequence of construction of the groins over a five-year period of time with estimated costs of construction.

1. CONCEPTUAL DESIGN OF SHORT STONE GROIN

The plan under consideration for adoption at Ocean City is known as the "short groin" plan and is described in some detail in pages 8-18 in Trident's "Interim Beach Maintenance at Ocean City" Final Report, dated August 30, 1979. A sketch of the short groin, as designed, and the estimated resulting beach profiles is shown in Figure 1.

In reviewing this design, it should be recognized that the design is based principally on two things:

- The average beach profile in the area; and
- The "initiation point", the point of intersection of this profile with the mean high water datum plane.

Thus, the outer end of the groin is set at a distance 215 feet seaward of the intersection of the average profile with the mean high water datum plane.

It also has to be recognized that the beach sections (or beach fillets) between a pair of groins will, most of the time, not be parallel to the shore — as is explained on pages 11-13 of the Final Report. This will result in the beach being wider at one end (usually the south end) than at the other end by as much as 90 feet. Thus, there are two beach profiles shown in Figure 1: one profile for the "thin" portion of the beach, and one for the "wide" portion.

At the time the groins are designed as a "final design", care must be taken in identifying the initiation point (the point of intersection of the "thin beach profile" and the MHW line). If the beach is deemed to be too thin with the existing condition of the beach at that time, then the initiation point must be moved seaward the additional width needed and the groin profile itself moved seaward this same amount.

2. LOCATION OF GROINS

On the Ocean City beach, there are presently 42 groins that have been constructed during the past 56 years, from 1922 to 1978. Of these 42 groins, there are 14 groins located in the first mile of beach as measured in a northerly direction from the North Jetty at the Ocean City Inlet. These 14 groins are mainly buried under the sand of the shorefront. (The groin located between 10th and 11th Streets is the only groin visable at present.) The distance from the North Jetty at the Ocean City Inlet to the groin located between 10th and 11th Streets is ±6030 feet or ±1.14 miles. The 1.14 miles of shorefront contains an accretion of sand which has been built up from the influence of the North Jetty since its construction in the 1930's.

For the proposed new groin placement, it is not recommended that groins are needed in this first mile section of the Ocean City beach. From the location of the groin between 10th and 11th Streets to the Maryland-Delaware line, it is approximately eight miles. It is within this eight-mile section that it is proposed that new groins should be constructed to protect against shore erosion.

Groin Spacing

The "Shore Protection Manual" (see Appendix B of Preliminary Report) recommends that the spacing of the groins be two to three times the working length of the groin. Using the higher figure, the groin spacing would be:

- Short groins 280* x 3 = 840 feet

  * *For the 330-foot short groin designed for Ocean City, 280 feet of the total length is considered as its "working" length.*

If the groins were to be spaced at exactly 840 feet apart, 50 groins would be needed to span the eight miles of shorefront. Spacing the new groins to utilize existing groins where a new groin could be built as an extension of an existing groin, 47 groins are recommended for this eight-mile section. As can be seen in Figure 2, all existing groins that are within ±80 feet of the recommended spacing of 840 feet between groins have been used as a location for a new groin. This slight deviation from the recommended spacing utilizes all possible existing groins that can be used as an extension. As the entire eight miles of shorefront is to function as a single integrated groin field, the slight deviation of ±80 feet for a few of the groins from the recommended spacing of 840 feet between groins is not considered a significant change to the basic design.

To maintain the ±840-foot spacing between the groins as close to this distance as possible, three of the seven stone groins that are scheduled for construction in 1979 should be moved from their planned location by some ±200 feet. These three groins are presently scheduled to be placed at 125th, 83rd, and 60th Streets. As noted in Figure 2, the 125th Street groin should be moved ±200 feet to the north to maintain the proper distance from the existing groin at 128th Street. The new stone groin at 83rd Street should also be moved ±200 feet to the north to maintain the proper spacing from the existing groin at 91st Street, and the new stone groin for 60th Street should be moved ±200 feet to the south. If these changes are made, all groins as depicted in Figure 2 will then be within ±80 feet of the recommended 840-foot spacing between groins, and all existing groins that are within this interval of spacing will be utilized for extension.

It should be noted that the locations of the existing groins as shown in Figure 2 were derived from plans received from the Corps of Engineers and the Department of Natural Resources. Field verification of actual locations of the groins was not made. This drawing is for a conceptual plan only; and before groin construction is started, a survey should be made of each existing groin to ensure that its location is accurate as shown on this drawing and, most important, that the groin is structurally sound and can be used for the base of an extended stone groin.

3. IMPLEMENTATION PLAN

On pages 16-18 of the "Interim Beach Maintenance at Ocean City" Final Report, the sequence of construction and the methods of sand fill or placement of sand between groins in the "groin pocket" are discussed. Briefly, this section of the report states:

> If the groin pockets are not artifically filled with sand at the time of construction, it will take probably seven to eight years of time to construct all short groins. This is estimated at the fill rate of some six groins per year. This amount of time is needed to allow the groins to fill with sand from the littoral drift before additional groins are constructed.
>
> Using this method, some erosion may take place at the north end of each groin pocket. Additionally, a significant amount of the littoral drift sand presently being passed along the shorefront would be retained in the groin pockets and would thus be taken out of the littoral drift system that deposits this sand in other locations along the shorefront, including the shorefront of mile 1, north of the North Jetty at Ocean City.
>
> The recommended method to prevent erosion in the groin pockets and to not deprive the littoral drift of significant quantities of sand is to fill each groin pocket artifically at the time of construction. This method will also allow construction to proceed as fast as a contractor can build the required number of groins per year.

Assuming that ten groins can be built each year and filled at the time of construction, the Ocean City groin system could be completed in approximately five years.

As previously stated, groin construction should start at the south end of the beach and proceed north. In the southerly section of the beach, the first ten groins to be constructed would be from 9th Street to 31st Street. In this section, ten existing timber groins are properly spaced for use to be extended by the new stone groins.

The first year's cost would thus be for ten stone groin extensions to existing timber groins. The actual length of stone groin needed as an extension to an existing timber groin cannot be accurately determined without a field survey and determination of the desired height of all groins for the Ocean City beach environment. However, it is estimated that the stone groin should be at least 129 feet long. This would tie the stone groin into the timber groin approximately at the MHW line of the "wide section" of the beach fillet (see Figure 1). It might be desirable to extend the stone groin further into the shorefront, but this would need to be determined by field survey and final design considerations.

The important factor would be to make certain that there is a proper "tie-in" between the wood piling section and the rock section. One way of doing this would be to consider the timber groin as a "center board" for a portion of the rock groin. Under this concept, the rock groin would be brought shoreward sufficiently to overlap the wood section for a distance of 15 to 20 feet. The rock section in the overlap would be retained at the same section as would be used if no wood groin were present. The wood section would then be along the centerline of the overlapping rock section.

The rock section would, of course, be discontinued after the 15 or 20 feet of overlap had been obtained and the wood section left to provide the remaining groin section to the back of the beach.

Groin Construction Costs

Estimated cost for a stone groin of the approximate size and cross-section dimensions recommended for the Ocean City environment is $473.64/linear foot*.

---

* The $473.64/linear foot cost for stone groins is based on an estimated cost of groins furnished by the Philadelphia Corps of Engineers.

1st Year Cost

Groins — Extension of 129 feet of new stone groins to ten existing timber groins

$473.64 x 129 feet = $61,100.00 ea.

x 10 groins = $611,000.00

Sand Fill — 20,120 yd^3 for each groin pocket

x 9 pockets of 10 groins = 181,080 yd^3

x $6.00**/$yd^3$ = $1,086,480.00

TOTAL COST 1ST YEAR..............$1,697,480.00

2nd Year Cost

10 groins from 34th Street to north of Maryland Route 90 location (see Figure 1). In this section there is one timber groin and two (1979) stone groins that can be used for extensions. Seven new stone groins would be needed.

3 extension groins x $61,100.00 ea. = $ 183,300.00

7 new stone groins ($473.64 x 330 feet)

$156,301.00 ea. x 7 = $1,094,108.00

Total for Groin Construction.....$1,277,408.00

Sand Fill — 20,120 yd^3 for each groin pocket

x 10 pockets of 10 groins = 201,200 yd^3

x $6.00/$yd^3$ = $1,207,200.00

TOTAL COST 2ND YEAR..............$2,484,608.00

**$6.00/$yd^3$ cost for sand is based on September 1979 estimates received from the Baltimore District Corps of Engineers from their latest revision of their Beach Erosion Study. The Baltimore office provided us a $4.00/$yd^3$ cost based on their 1977 data which was used in our Final Report for this study. Actual costs incurred at the date the dredging is to be accomplished may vary considerably.

3rd Year Cost

10 groins from north of Maryland Route 90 location to 93rd Street. In this section, there are four existing timber groins and two (1979) stone groins that can be used for extensions. Four new stone groins would be needed.

6 extension groins @ \$61,100.00 ea. = \$366,600.00

4 new stone groins @ \$156,301.00 ea. = \$625,204.00

Total for Groin Construction........\$ 991,804.00

Sand Fill — 10 groin pockets = 201,200 yd^3
x \$6.00/yd^3 = \$1,207,200.00

TOTAL COST 3RD YEAR.................\$2,199,004.00

4th Year Cost

10 groins from 98th Street to 128th Street. In this section, there are two existing timber groins and three (1979) stone groins that can be used for extensions. Five new stone groins will be needed.

5 extension groins @ \$61,100.00 ea. = \$305,500.00

5 new stone groins @ \$156,301.00 ea. = \$781,505.00

Total for Groin Construction........\$1,087,005.00

Sand Fill — 10 groin pockets = 201,200 yd^3
x \$6.00/yd^3 = \$1,207,200.00

TOTAL COST 4th YEAR.................\$2,294,205.00

5th Year Cost

7 groins from north of 130th Street to the Maryland-Delaware line. All groins are new stone groins.

7 new stone groins @ $156,301.00 ea.	=	$1,094,107.00
Sand Fill — 7 groins pockets = 140,840 yd^3 x $6.00/$yd^3$	=	$ 845,040.00
TOTAL COST 5TH YEAR		$1,939,147.00

Total Cost

Total costs for 47 groins and sand fill over five-year period.

Groin Construction	$ 5,061,324.00
Sand Fill	$ 5,553,120.00
GRAND TOTAL	$10,614,444.00

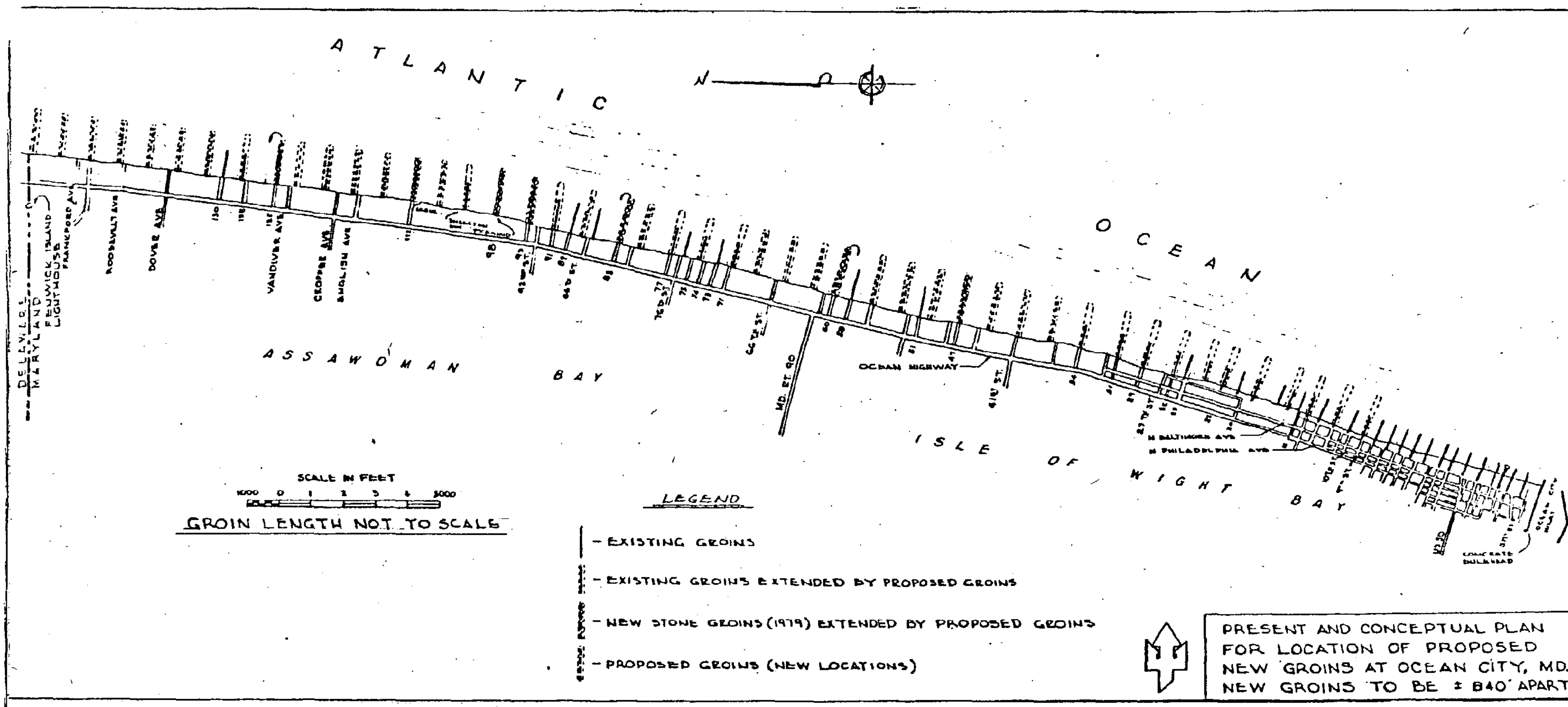
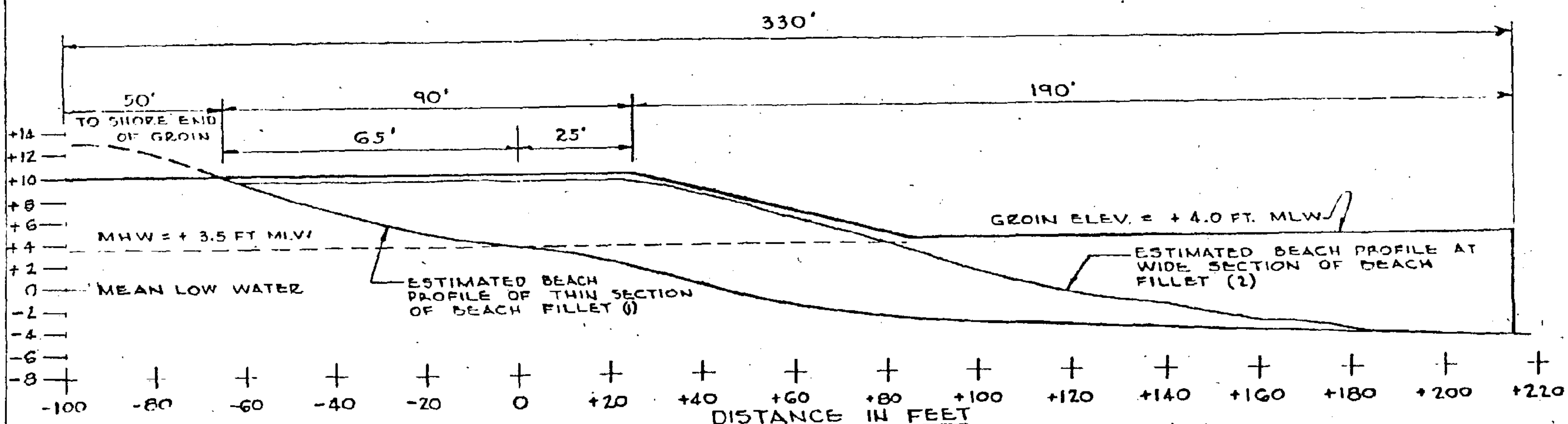

ATLANTIC OCEAN
ASSAWOMAN BAY
ISLE OF WIGHT BAY
DELAWARE
MARYLAND
FENWICK ISLAND LIGHTHOUSE
FRANKFORD AVE
ROOSEVELT AVE
DOVER AVE
VANDIVER AVE
CROPPER AVE
ENGLISH AVE
MD. RT. 90
OCEAN HIGHWAY
N BALTIMORE AVE
N PHILADELPHIA AVE
SCALE IN FEET
1000 0 1 2 3 4 5000
GROIN LENGTH NOT TO SCALE
LEGEND
- EXISTING GROINS
- EXISTING GROINS EXTENDED BY PROPOSED GROINS
- NEW STONE GROINS (1979) EXTENDED BY PROPOSED GROINS
- PROPOSED GROINS (NEW LOCATIONS)
PRESENT AND CONCEPTUAL PLAN
FOR LOCATION OF PROPOSED
NEW GROINS AT OCEAN CITY, MD.
NEW GROINS TO BE ± 840' APART

FIGURE 2



NOTES

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(2) THE "WIDE" SECTION OF THE FILLET AS SHOWN ASSUMES THAT THE GROINS HAVE BEEN CONSTRUCTED AND THE GROINS FILLED BY PLACING APPROXIMATELY 20,120 CU. YDS. OF SAND BETWEEN EACH PAIR OF GROINS.

CONCEPTUAL PLAN

INTERIM BEACH MAINTENANCE STUDY
OCEAN CITY, MD.
GROIN PROFILES & ESTIMATED BEACH
PROFILES WITH SHORT GROINS

FIGURE 1

Section V
pages 1-18

FINAL REPORT FOR ADDITIONAL DATA
OF TRIDENT'S REPORT ON INTERIM BEACH MAINTENANCE
AT OCEAN CITY

Prepared for

TIDEWATER ADMINISTRATION
DEPARTMENT OF NATURAL RESOURCES
STATE OF MARYLAND
Tawes State Office Building
Annapolis, Maryland 21401

From

TRIDENT ENGINEERING ASSOCIATES, INC.
48 Maryland Avenue
Annapolis, Maryland 21401

FINAL REPORT FOR ADDITIONAL DATA
OF TRIDENT'S REPORT
ON INTERIM BEACH MAINTENANCE
AT OCEAN CITY

October 1979

FINAL REPORT FOR ADDITIONAL DATA OF TRIDENT'S REPORT ON INTERIM BEACH MAINTENANCE AT OCEAN CITY

The material presented within this report, less Figures 2 through 6 and the first paragraph of the Preliminary Groin Design section, was previously presented in a handout to the Coastal Resources Advisory Committee (CRAC) on October 5, 1979. Since that period of time, Trident has prepared the preliminary design cross-sections for the short groins, which are included within this report as Figures 2 through 6.

Trident previously studied alternative shore erosion control measures that could be implemented by the State as an interim measure prior to the time the Corps of Engineers plans will be initiated. These alternative erosion control measures are contained within our "Interim Beach Maintenance at Ocean City" Preliminary Report dated July 19, 1979. The Ocean, Bays, and Beaches Subcommittee and the Department of Natural Resources (DNR) selected three of the alternative measures -- long groins (465 feet long), short groins (330 feet long), and beach fill methods -- for further study, which are contained within our Final Report dated August 30, 1979. From the presentation of the Final Report on September 10, 1979, the selection was made by the Ocean, Bays, and Beaches Subcommittee to recommend construction of the short groins at Ocean City.

Since that period of time, the DNR has requested Trident to provide additional information consisting of:

1. Typical cross-sections of a conceptual design of the short stone groin;

2. Recommended locations and spacing of the short stone groins on the Ocean City beach, considering use of existing groins that can be extended to the recommended length of 330 feet;

3. Implementation plan or sequence of construction of the groins over a five-year period of time with estimated costs of construction.

1. CONCEPTUAL DESIGN OF SHORT STONE GROIN

The plan under consideration for adoption at Ocean City is known as the "short groin" plan and is described in some detail in pages 8-18 in Trident's "Interim Beach Maintenance at Ocean City" Final Report, dated August 30, 1979. A sketch of the short groin, as designed, and the estimated resulting beach profiles is shown in Figure 1.

In reviewing this design, it should be recognized that the design is based principally on two things:

- The average beach profile in the area; and
- The "initiation point", the point of intersection of this profile with the mean high water datum plane.

Thus, the outer end of the groin is set at a distance 215 feet seaward of the intersection of the average profile with the mean high water datum plane.

It also has to be recognized that the beach sections (or beach fillets) between a pair of groins will, most of the time, not be parallel to the shore — as is explained on pages 11-13 of the Final Report. This will result in the beach being wider at one end (usually the south end) than at the other end by as much as 90 feet. Thus, there are two beach profiles shown in Figure 1: one profile for the "thin" portion of the beach, and one for the "wide" portion.

At the time the groins are designed as a "final design", care must be taken in identifying the initiation point (the point of intersection of the "thin beach profile" and the MHW line). If the beach is deemed to be too thin with the existing condition of the beach at that time, then the initiation point must be moved seaward the additional width needed and the groin profile itself moved seaward this same amount.

Preliminary Groin Design

Figures 2 through 6 are the five cross-sections which are preliminary concepts of the Ocean City short groins. Short groins were previously described in Trident's Final Report.

CROSS-SECTIONS

For all cross-sections, the actual design water level was assumed to be +3.5 feet additional for high tide, and +3.5 feet additional for the added storm surge; e.g., the design water level elevation was 7 feet above mean low water. Use of the +7 feet MLW would ensure that the groin would be stable under severe storm wave conditions. For example, with an assumed water depth of -6 feet MLW at the head of the groin, the storm water elevation would be 6 ft. + 3.5 ft. + 3.5 ft. = 13 ft. This 13-foot depth would permit a 10.1-foot breaking wave to break on the head of the groin. Thus, the head of the groin is designed to withstand a breaking wave of a 10.1-foot height. A stone weight of 165 lbs/cu. ft. has been assumed for this design. The breaking height will be less as the water depth decreases. For example, at the mean low water beach line, the storm water depth would be 7 feet and the design wave becomes 5.5 feet.

The question of whether or not to provide a walkway on the groin should be left with the client. If a grouted walkway is to be provided, then the middle stones on the crown could be made smaller and the grouted mass used to provide the needed weight and strength. The walkway could be used for recreational fishing if the client desires this feature.

The crown width of the groin at each section is set to provide three armor stones across the crown. Under this criterion, the section of the groin at the mean low water section would be only six feet wide on the crown. This six feet would not be wide enough to serve as a roadway for heavy construction equipment. Thus, if a permanent roadway (for construction and maintenance) is desired on the groin, the cross-section in certain sections of the length would have to be widened to provide a wider crown.

The selection of the bottom elevation of the groin would require additional study before a final decision is made. The elevation of the bottom should be set at the lowest elevation expected at each groin's location during very severe eroded conditions of the shore. For example, the bottom profile at the end of the March 1962 storm might serve as a basis for setting the bottom elevation of the groin along its length. The bottom elevations shown on the five cross-sections should not be used as a final design feature. This feature should be left to the engineer making the final design for groin construction and placement.

Summary Statement

- The five cross-sections should not be accepted as final designs; rather they should be used to indicate the general features of the groin and provide guidance for making initial cost estimates.

- The location of the groin, Figure 1, is shown with reference to the average 1979 beach profile and the intersection of the mean high water line with the beach profile. If, in the final design, a wider beach is desired, then for specific groin locations, the entire groin should be shifted seaward to match the new profile position.

2. LOCATION OF GROINS

On the Ocean City beach, there are presently 42 groins that have been constructed during the past 56 years, from 1922 to 1978. Of these 42 groins, there are 14 groins located in the first mile of beach as measured in a northerly direction from the North Jetty at the Ocean City Inlet. These 14 groins are mainly buried under the sand of the shorefront. (The groin located between 10th and 11th Streets is the only groin visable at present.) The distance from the North Jetty at the Ocean City Inlet to the groin located between 10th and 11th Streets is ±6030 feet or ±1.14 miles. The 1.14 miles of shorefront contains an accretion of sand which has been built up from the influence of the North Jetty since its construction in the 1930's.

For the proposed new groin placement, it is not recommended that groins are needed in this first mile section of the Ocean City beach. From the location of the groin between 10th and 11th Streets to the Maryland-Delaware line, it is approximately eight miles. It is within this eight-mile section that it is proposed that new groins should be constructed to protect against shore erosion.

Groin Spacing

The "Shore Protection Manual" (see Appendix B of Preliminary Report) recommends that the spacing of the groins be two to three times the working length of the groin. Using the higher figure, the groin spacing would be:

° Short groins 280* x 3 = 840 feet

** For the 330-foot short groin designed for Ocean City, 280 feet of the total length is considered as its "working" length.*

If the groins were to be spaced at exactly 840 feet apart, 50 groins would be needed to span the eight miles of shorefront. Spacing the new groins to utilize existing groins where a new groin could be built as an extension of an existing groin, 47 groins are recommended for this eight-mile section. As can be seen in Figure 7, all existing groins that are within ±80 feet of the recommended spacing of 840 feet between groins have been used as a location for a new groin. This slight deviation from the recommended spacing utilizes all possible existing groins that can be used as an extension. As the entire eight miles of shorefront is to function as a single integrated groin field, the slight deviation of ±80 feet for a few of the groins from the recommended spacing of 840 feet between groins is not considered a significant change to the basic design.

To maintain the ±840-foot spacing between the groins as close to this distance as possible, three of the seven stone groins that are scheduled for construction in 1979 should be moved from their planned location by some ±200 feet. These three groins are presently scheduled to be placed at 125th, 83rd, and 60th Streets. As noted in Figure 7, the 125th Street groin should be moved ±200 feet to the north to maintain the proper distance from the existing groin at 128th Street. The new stone groin at 83rd Street should also be moved ±200 feet to the north to maintain the proper spacing from the existing groin at 91st Street, and the new stone groin for 60th Street should be moved ±200 feet to the south.

In addition to the above listed recommended changes to maintain the 840 feet between groins to within ± 80 deviation, there are three other locations where the groin placement, as depicted in Figure 7, may exceed the ± 80-foot deviation:

- To be able to utilize the existing groin at 128th Street, the proposed groin to be placed north of 128th Street is approximately ± 1050 feet apart to provide equal distance between the new groins and the existing groin located at 130th Street;

- The new (1979) stone groins to be located at 93rd and 98th Streets are approximately 1000 feet apart but were left in this projected location to fit an equal distance between the existing groins at 91st Street and in front of the Sheraton Inn;

- The existing timber groins at 31st and 34th Streets are approximately 1100 feet apart, as depicted in Figure 7. This additional distance is not considered to be great enough to warrant construction of an additional groin between 31st and 34th Streets.

It should be noted that the locations of the existing groins as shown in Figure 7 were derived from plans received from the Corps of Engineers and the Department of Natural Resources. Field verification of actual locations of the groins was not made. This drawing is for a conceptual plan only; and before groin construction is started, a survey should be made of each existing groin to ensure that its location is accurate as shown on this drawing and, most important, that the groin is structurally sound and can be used for the base of an extended stone groin.

3. IMPLEMENTATION PLAN

On pages 16-18 of the "Interim Beach Maintenance at Ocean City" Final Report, the sequence of construction and the methods of sand fill or placement of sand between groins in the "groin pocket" are discussed. Briefly, this section of the report states:

> If the groin pockets are not artifically filled with sand at the time of construction, it will take probably seven to eight years of time to construct all short groins. This is estimated at the fill rate of some six groins per year. This amount of time is needed to allow the groins to fill with sand from the littoral drift before additional groins are constructed.
>
> Using this method, some erosion may take place at the north end of each groin pocket. Additionally, a significant amount of the littoral drift sand presently being passed along the shorefront would be retained in the groin pockets and would thus be taken out of the littoral drift system that deposits this sand in other locations along the shorefront, including the shorefront of mile 1, north of the North Jetty at Ocean City.
>
> The recommended method to prevent erosion in the groin pockets and to not deprive the littoral drift of significant quantities of sand is to fill each groin pocket artifically at the time of construction. This method will also allow construction to proceed as fast as a contractor can build the required number of groins per year.

Assuming that ten groins can be built each year and filled at the time of construction, the Ocean City groin system could be completed in approximately five years.

As previously stated, groin construction should start at the south end of the beach and proceed north. In the southerly section of the beach, the first ten groins to be constructed would be from 9th Street to 31st Street. In this section, ten existing timber groins are properly spaced for use to be extended by the new stone groins.

The first year's cost would thus be for ten stone groin extensions to existing timber groins. The actual length of stone groin needed as an extension to an existing timber groin cannot be accurately determined without a field survey and determination of the desired height of all groins for the Ocean City beach environment. However, it is estimated that the stone groin should be at least 129 feet long. This would tie the stone groin into the timber groin approximately at the MHW line of the "wide section" of the beach fillet (see Figure 1). It might be desirable to extend the stone groin further into the shorefront, but this would need to be determined by field survey and final design considerations.

The important factor would be to make certain that there is a proper "tie-in" between the wood piling section and the rock section. One way of doing this would be to consider the timber groin as a "center board" for a portion of the rock groin. Under this concept, the rock groin would be brought shoreward sufficiently to overlap the wood section for a distance of 15 to 20 feet. The rock section in the overlap would be retained at the same section as would be used if no wood groin were present. The wood section would then be along the centerline of the overlapping rock section.

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Groin Construction Costs

Estimated cost for a stone groin of the approximate size and cross-section dimensions recommended for the Ocean City environment is $473.64/linear foot*.

---

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$473.64 x 129 feet	= $61,100.00 ea.		
x 10 groins		=	$611,000.00
Sand Fill — 20,120 yd³ for each groin pocket			
x 9 pockets of 10 groins = 181,080 yd³			
x $6.00**/yd³		=	$1,086,480.00
TOTAL COST 1ST YEAR..............			$1,697,480.00

2nd Year Cost

10 groins from 34th Street to north of Maryland Route 90 location (see Figure 1). In this section there is one timber groin and two (1979) stone groins that can be used for extensions. Seven new stone groins would be needed.

3 extension groins x $61,100.00 ea.	=	$ 183,300.00
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Total for Groin Construction.....		$1,277,408.00
Sand Fill — 20,120 yd³ for each groin pocket		
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Sand Fill — 10 groin pockets = 201,200 yd^3
x \$6.00/yd^3 = \$1,207,200.00

TOTAL COST 3RD YEAR..................\$2,199,004.00

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10 groins from 98th Street to 128th Street. In this section, there are two existing timber groins and three (1979) stone groins that can be used for extensions. Five new stone groins will be needed.

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5 new stone groins @ \$156,301.00 ea. = \$781,505.00

Total for Groin Construction........\$1,087,005.00

Sand Fill — 10 groin pockets = 201,200 yd^3
x \$6.00/yd^3 = \$1,207,200.00

TOTAL COST 4th YEAR..................\$2,294,205.00

5th Year Cost

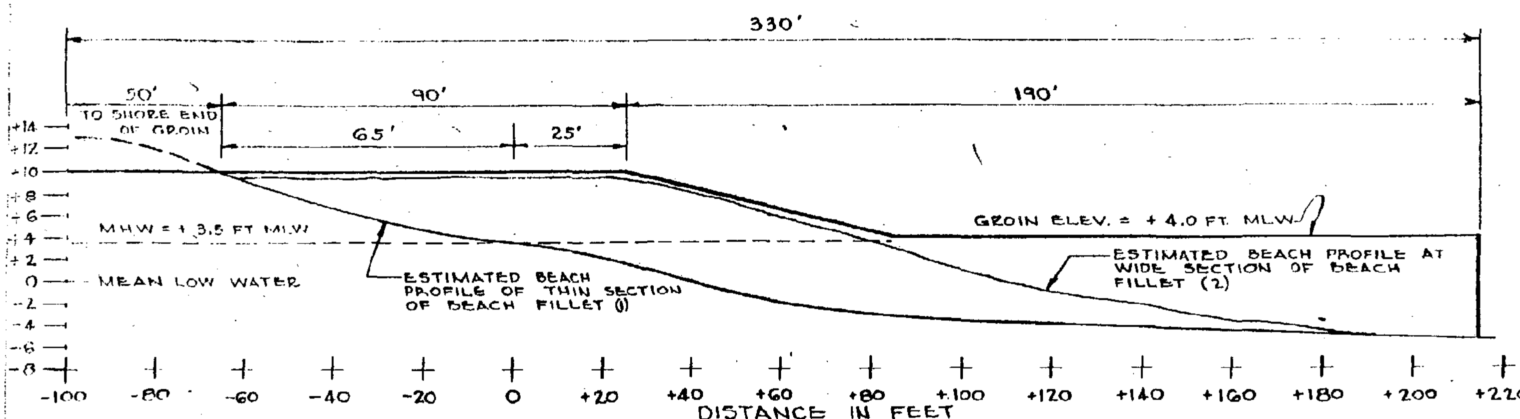
7 groins from north of 130th Street to the Maryland-Delaware line. All groins are new stone groins.

7 new stone groins @ \$156,301.00 ea.	=	\$1,094,107.00
Sand Fill — 7 groins pockets = 140,840 yd^3 x \$6.00/yd^3	=	\$ 845,040.00
TOTAL COST 5TH YEAR		\$1,939,147.00

Total Cost

Total costs for 47 groins and sand fill over five-year period.

Groin Construction	\$ 5,061,324.00
Sand Fill	\$ 5,553,120.00
GRAND TOTAL	\$10,614,444.00



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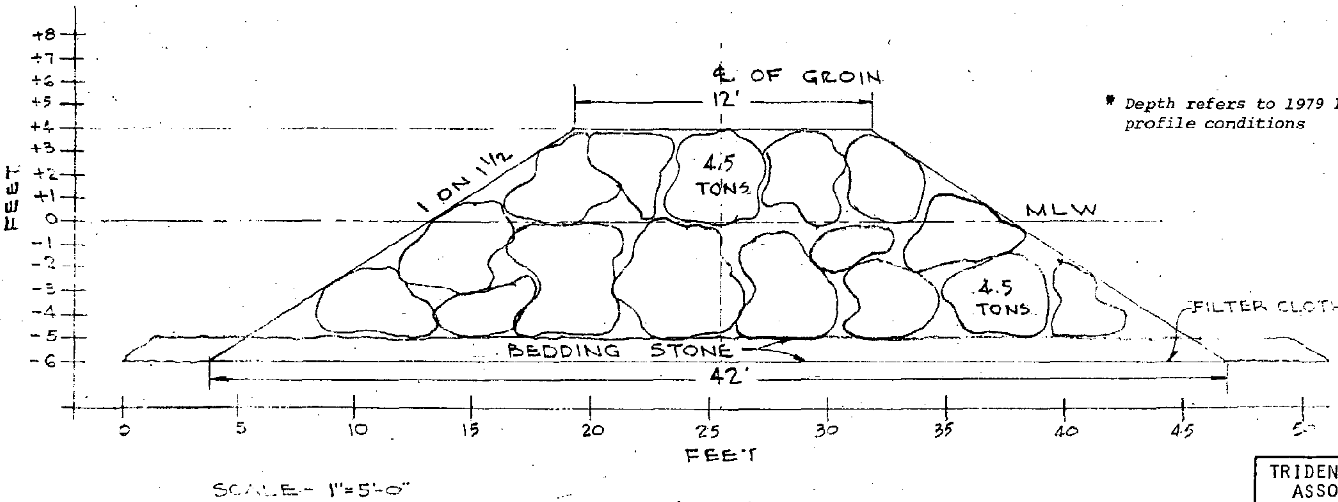
CONCEPTUAL PLAN

INTERIM BEACH MAINTENANCE STUDY
OCEAN CITY, MD.
GROIN PROFILES & ESTIMATED BEACH PROFILES WITH SHORT GROINS

FIGURE 1

PRELIMINARY DESIGN OF OCEAN CITY GROINS

CROSS-SECTION OF HEAD OF GROIN IN -6 FOOT DEPTH*



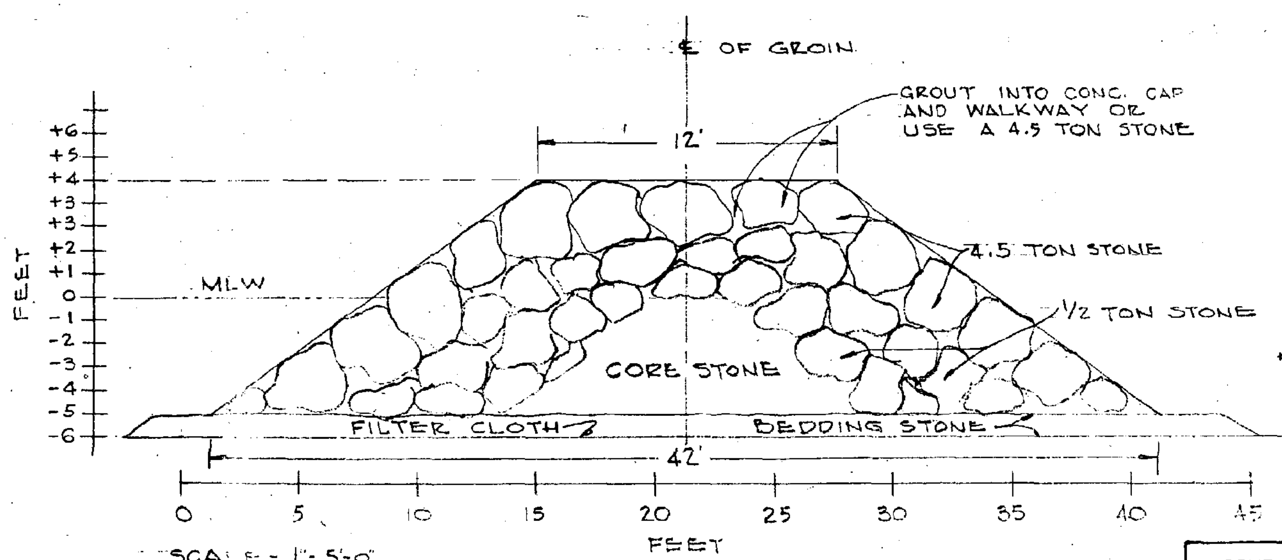
* Depth refers to 1979 beach profile conditions

Figure 2

TRIDENT ENGINEERING ASSOCIATES, INC.
ANNAPOLIS, MARYLAND
OCTOBER 1979 [JMC]

PRELIMINARY DESIGN OF OCEAN CITY GROINS

CROSS-SECTION OF TRUNK OF GROIN IN -6 FOOT DEPTH*



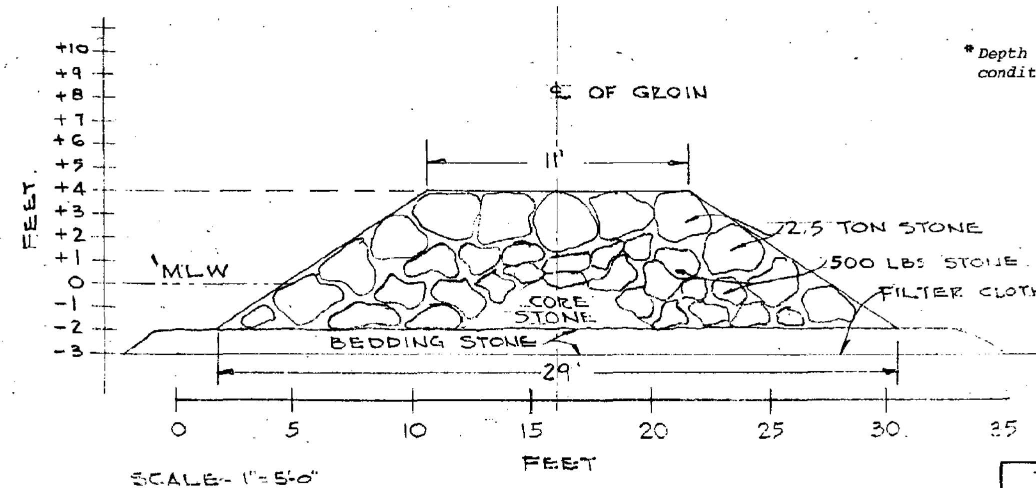
*Depth refers to 1979 profile conditions

Figure 3

TRIDENT ENGINEERING ASSOCIATES, INC.
ANNAPOLIS, MARYLAND
OCTOBER 1979 [JMC]

PRELIMINARY DESIGN OF OCEAN CITY GROINS

CROSS-SECTION OF TRUNK OF GROIN IN -3 FOOT DEPTH*



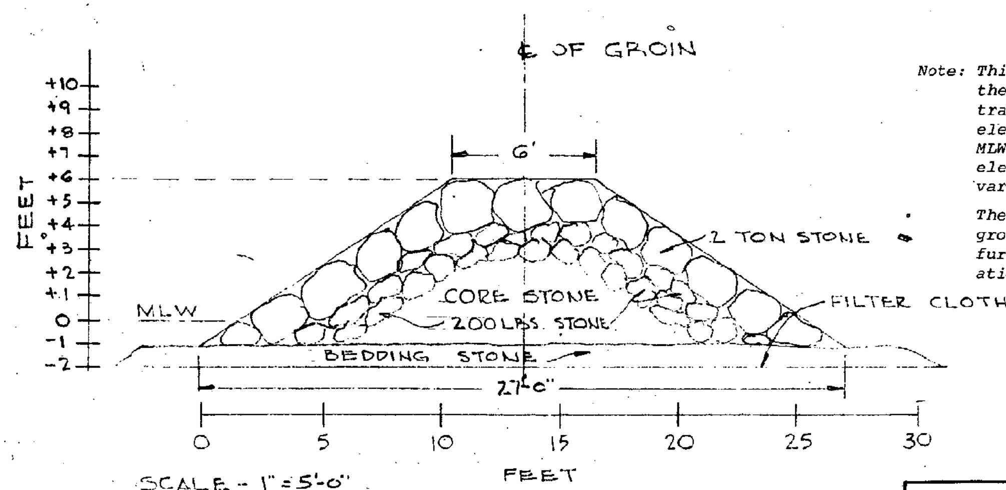
*Depth refers to 1979 profile conditons

Figure 4

TRIDENT ENGINEERING
ASSOCIATES, INC.
ANNAPOLIS, MARYLAND
OCTOBER 1979 [JMC]

PRELIMINARY DESIGN OF OCEAN CITY GROINS

CROSS-SECTION IN VICINITY OF THE MEAN LOW WATER LINE
ON THE 1979 BEACH PROFILE



Note: This groin section is in the area of the groin transition from a crown elevation of +4 to +10 feet MLW. The top and bottom elevations would, therefore, vary along the slope.

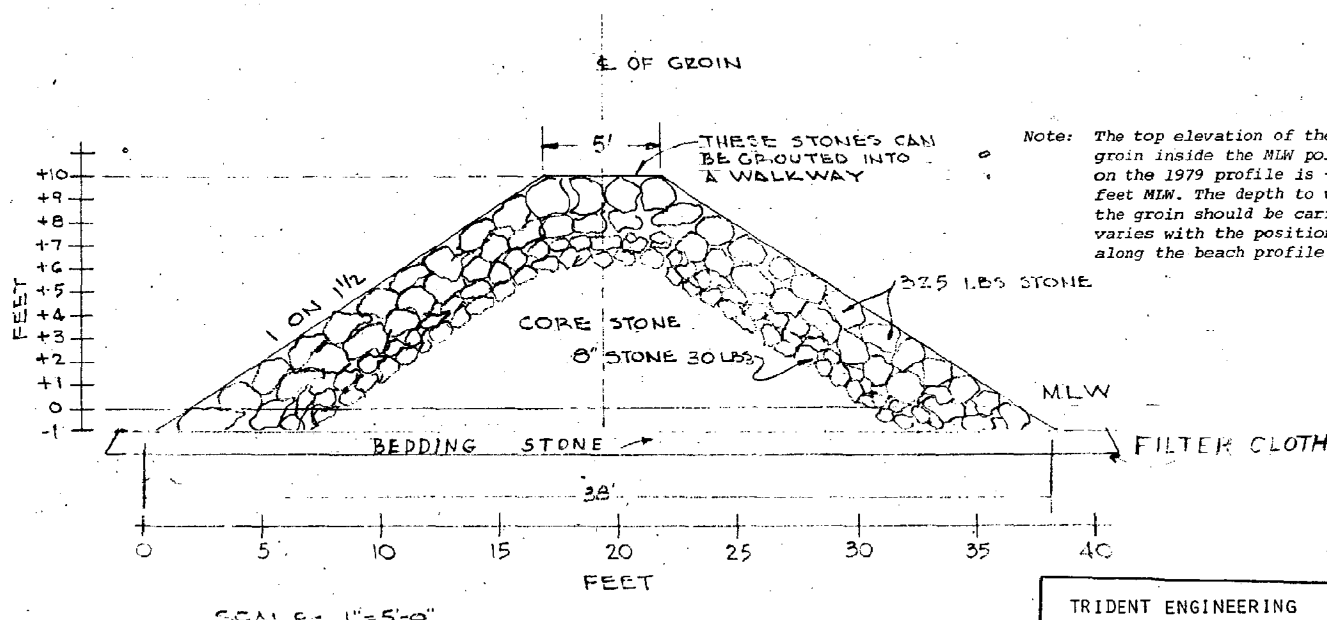
The foundation depth of the groin should be selected after further study of local variations in depth under storm wave conditions.

Figure 5

TRIDENT ENGINEERING
ASSOCIATES, INC.
ANNAPOLIS, MARYLAND
OCTOBER 1979 [JMC]

PRELIMINARY DESIGN OF OCEAN CITY GROINS

CROSS-SECTION OF TRUNK OF GROIN NEAR AND SHOREWARD
OF THE +3 FOOT ELEVATION ON THE 1979 BEACH PROFILE



Note: The top elevation of the groin inside the MLW point on the 1979 profile is +10 feet MLW. The depth to which the groin should be carried varies with the position along the beach profile.

TRIDENT ENGINEERING
ASSOCIATES, INC.
ANNAPOLIS, MARYLAND
OCTOBER 1979 [JMC]

Figure 6

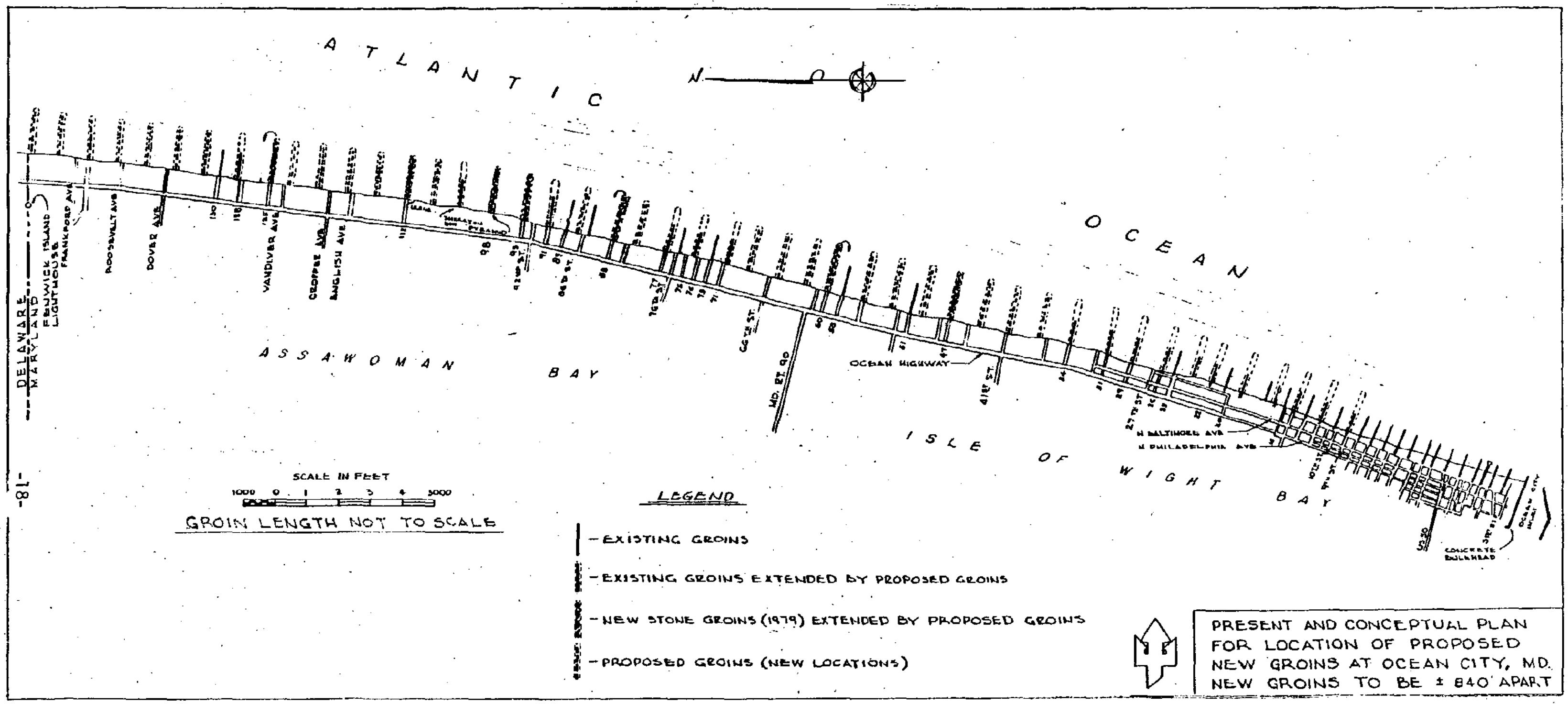

ATLANTIC OCEAN
N
ASSAWOMAN BAY
ISLE OF WIGHT BAY
DELAWARE
MARYLAND
FENWICK ISLAND LIGHTHOUSE
FRANKFORD AVE
ROOSEVELT AVE
DOVER AVE
VANDIVER AVE
CROPPER AVE
ENGLISH AVE
OCEAN HIGHWAY
MD. RT. 90
41ST ST.
N. BALTIMORE AVE
N. PHILADELPHIA AVE
CONCRETE BULKHEAD
OCEAN CITY INLET
SCALE IN FEET
1000 0 1 2 3 4 5000
GROIN LENGTH NOT TO SCALE
LEGEND
- EXISTING GROINS
- EXISTING GROINS EXTENDED BY PROPOSED GROINS
- NEW STONE GROINS (1979) EXTENDED BY PROPOSED GROINS
- PROPOSED GROINS (NEW LOCATIONS)
PRESENT AND CONCEPTUAL PLAN
FOR LOCATION OF PROPOSED
NEW GROINS AT OCEAN CITY, MD.
NEW GROINS TO BE ± 840' APART

FIGURE 7